basic television

REVISED EDITION

Volume 4

Alexander Schure

TV RECEIVER CIRCUIT EXPLANATIONS

H & V Sync Circuits • Sync Clippers • Oscillators
Multivibrators • Differentiation • Integration
Equalizing Pulses • High-Voltage Power Supply

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BASIC TELEVISION

Vol. 4

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Revised Edition Vol. 4

ALEXANDER SCHURE

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PREFACE

Fifteen years have passed since the initial publication of the five-volumed course dealing with basic principles of television. During these years we have seen extraordinary social and technological changes, ones which are now touching all aspects of our society. It seems more than likely that in the future these changes will evolve at an even more rapid rate. The world of the twenty-first century will be as different from that of today as our present world is from that which existed prior to the industrial revolution.

With each passing day we witness developments that are continually breaking with the past. In this last decade alone, we have moved from jet travel to space travel, from limitations of travel within the atmosphere of earth to the capacity to probe Mars and beyond. Electronics, too, has progressed with similar speed. Color television, facsimile, computers, transistors, and LSI memories are all recent products.

The present six-volumed course represents substantial modifications of the original basic television programs. In addition, particular emphasis has been given to the development of color TV and the introduction of new solid-state approaches. The heavily illustrated format adapted throughout the initial volumes has been retained. The combination of text and illustrations has been chosen in order to place particular emphasis on essential materials, and, in addition, review sections are interspersed throughout each volume in an effort to capsulize major points covered in the body of the text. As a result, the overall visual approach and programmed sequence coverage is comprehensive, from the creation of the television image in the studio to its appearance on the home screen, and presupposes only a knowledge of basic electronics.

The author wishes to acknowledge the substantial contributions of Messrs. Harvey Pollack, Charles J. Anderson, Jr., Fred R. Kulis, and Anthony S. Santonelli in the updating of these volumes.

Alexander Schure

Old Westbury, New York

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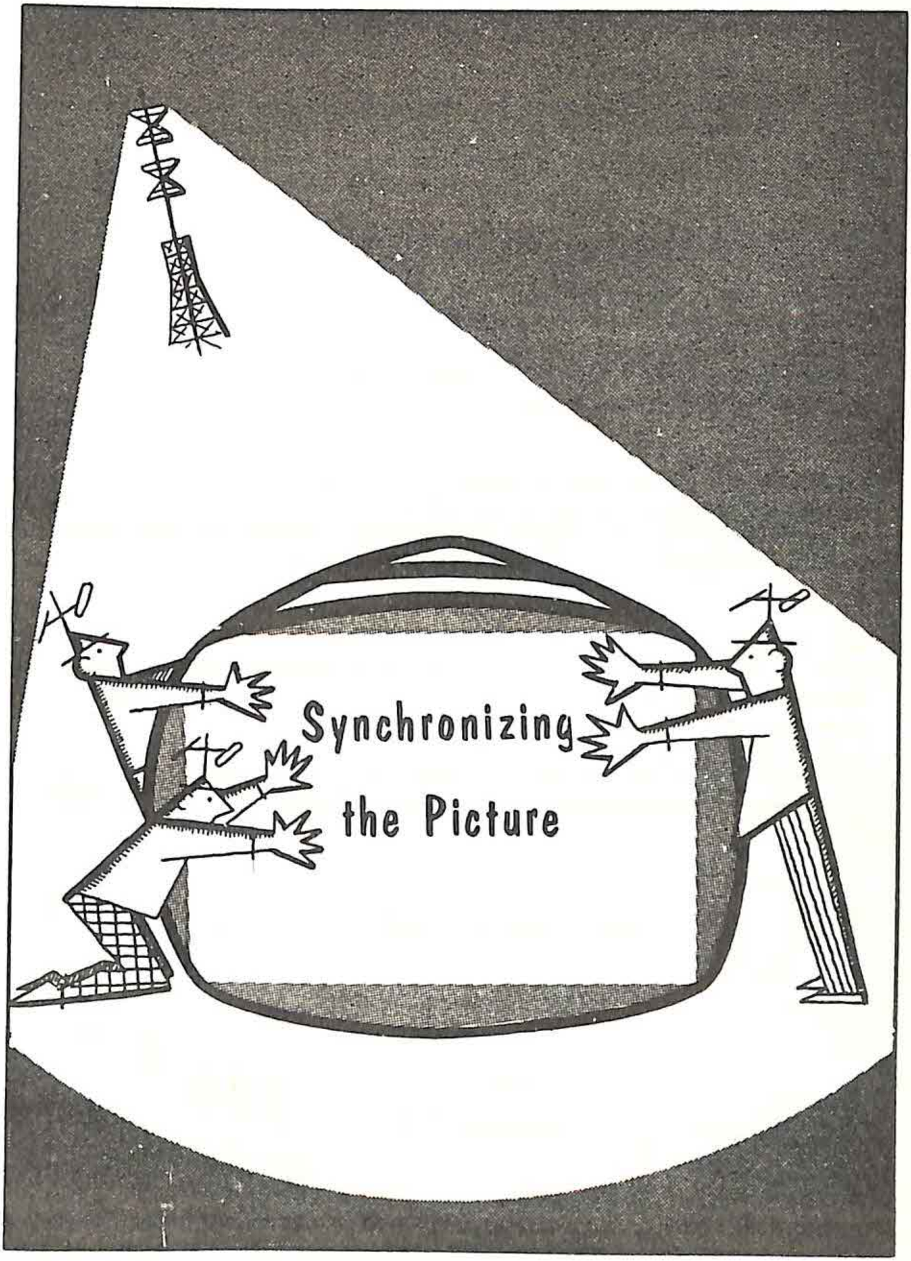

Synchronizing
the Picture

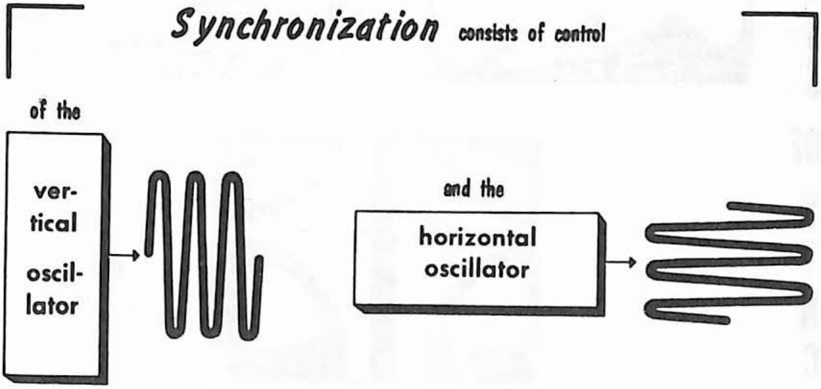
Synchronizing the Picture

We have already discussed the system which controls the frequency of the horizontal sweep oscillator. We might mention that the horizontal sweep oscillator is the source of the voltage which eventually results in horizontal deflection currents that flow in the horizontal winding of the deflection yoke.

We also related the horizontal scanning lines developed on the picture tube screen to the frequency of the horizontal sweep oscillator. The horizontal sweep oscillator functions at 15,750 Hz and is kept on this frequency by the horizontal synchronizing signal from the transmitter. These pulses appear within the horizontal blanking intervals and are compared with the signal generated by the horizontal sweep oscillator. The result of the comparison is a frequency-controlling voltage which fixes the frequency of the horizontal sweep oscillator.

Control of the horizontal sweep oscillator is only one of the operations necessary for the reproduction of a televised image on the screen of a receiver picture tube. It is necessary to control the vertical movement of the electron beam in the picture tube with equal accuracy. This is accomplished by a special 60-Hz voltage generated in the receiver.

Control of the frequency of the currents that flow in the horizontal and vertical deflection windings of the deflection yoke (the currents which move the beam of the picture tube vertically and horizontally) is very important indeed. But this is not the whole story. The beam in the picture tube must move across the screen surface in perfect step with the beam in the camera tube at the studio. Moment by moment the relative positions of these two beams on the picture tube screen and on the camera tube mosaic, respectively, must be the same.



Synchronizing the Picture (cont'd)

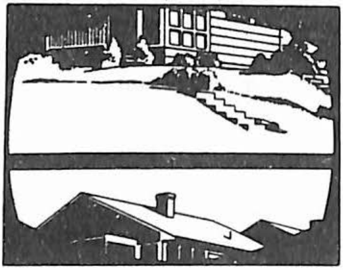
Synchronization of the picture, therefore, involves not just the accurate control of the horizontal and vertical sweep oscillators, or the two blanking actions, but also the correct timing between the start of the horizontal sweep and retrace—and the start of the vertical sweep and retrace—in the picture tube and in the camera tube.

If these two actions are not synchronized, the reproduced image of the televised scene becomes unintelligible. Here are several examples of the results of incorrect picture synchronization. When both horizontal and vertical sweep oscillators are off frequency, the picture is virtually unrecognizable. Even when only one of the two sweep oscillators is unsynchronized the picture remains virtually useless.

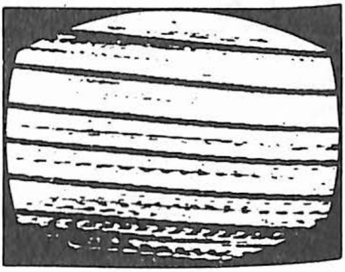
All the imperfectly synchronized examples have one thing in common—the positioning of the electron beam on the picture tube screen does not conform with the positioning of the scanning beam on the camera tube mosaic moment by moment. To position this beam, the sweep oscillators in the receiver must be placed under the control of the horizontal and vertical sync pulses generated in the transmitter and radiated to the receiver as a part of the television signal.

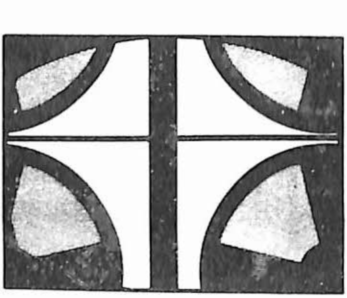
LOSS OF SYNC

Vertical Sync



Horizontal Sync





Horizontal and Vertical Sync

Vertical Deflection Control Signals

Refer for a moment to the scanning principles you studied in Volume 1. You'll recall that the control of the vertical motion of the picture tube beam—the scan from the top of the tube screen to the bottom, and the vertical retrace which returns the beam to the top—is just as critical as the horizontal motion. The downward motion of the beam must start at a precise moment relative to the horizontal motion. The full excursion of the picture tube beam in the downward direction for a field must be completed within a prescribed time interval, specifically in 15,500 μsec (microseconds). The retrace action must take place in 1167 μsec.

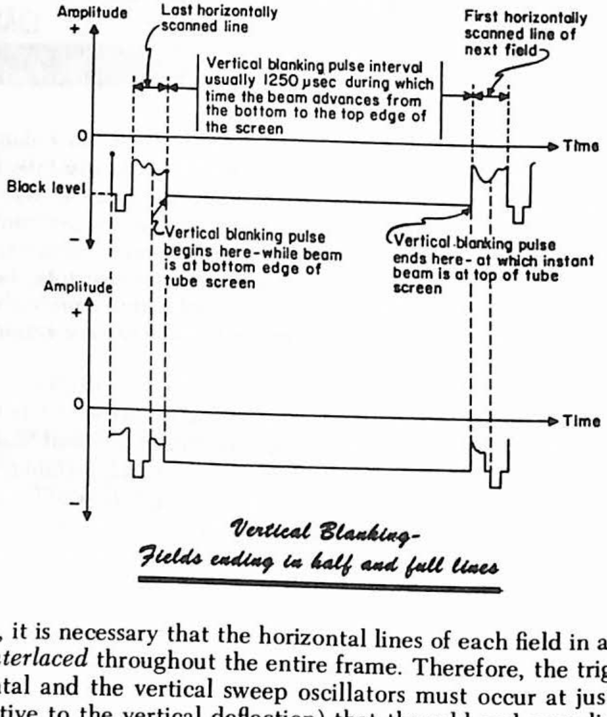
If we allowed the beam to form luminous lines on the screen while the vertical retrace was active it would impair the picture. Hence, vertical blanking is required during the retrace. This action too must begin at a certain moment and end at a certain moment, with about 1250 μsec being allowed for its duration. The mere statement that the vertical sweep frequency is 60 Hz and that a vertical sweep cycle is completed in 1/60 sec does not really tell what happens in this time interval.

As a matter of fact, if we reexamine the organization of the two fields which form a frame, we note several details that are very pertinent to the timing relationship between the vertical and the horizontal sweep actions. We are referring to the dissimilarity at the beginning and the ends of the two fields. In one case the field *starts* with a whole horizontal line, with its beginning point at the left top of the screen, and *ends* with a horizontal half line at the bottom of the screen.

The next field *starts* with a horizontal half line, with its beginning at the middle of the top and *ends* with a whole line at the right bottom of the screen. While it is true that each field consists of 262.5 lines, the starting points for the vertical and horizontal beam deflection at the top of the screen are unlike in the two fields, as are the completion points of the deflection action for the two fields.

Vertical Deflection Control Signals (cont'd)

There is, therefore, present in each field an actual difference in the moment when the horizontal sweep oscillator trace comes out of blanking and reappears on the screen. It is triggered 525 times every two fields, each time producing a whole horizontal line (63.5 μsec long) which corresponds to a frequency of 15,750 Hz. Once in each field, however, the horizontal trace must produce a half line, and the time occupied by this half line on the screen is about 31.75 μsec.


Amplitude
+
Last horizontally scanned line
First horizontally scanned line of next field
Vertical blanking pulse interval usually 1250 μsec during which time the beam advances from the bottom to the top edge of the screen
0
Time
Black level
-
Vertical blanking pulse begins here-while beam is at bottom edge of tube screen
Vertical blanking pulse ends here- at which instant beam is at top of tube screen
Amplitude
+
0
Time
-

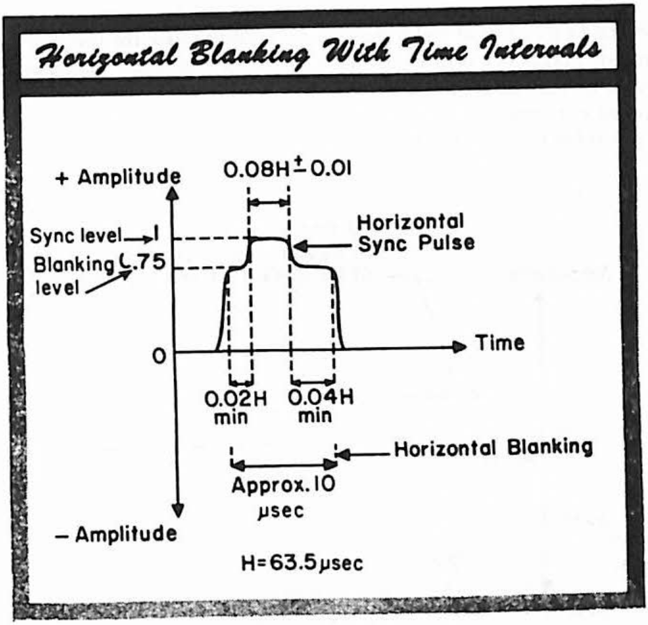
Vertical Blanking-
Fields ending in half and full lines

In addition, it is necessary that the horizontal lines of each field in a frame be correctly *interlaced* throughout the entire frame. Therefore, the triggering of the horizontal and the vertical sweep oscillators must occur at just the moments (relative to the vertical deflection) that the odd and even lines of the two frame fields are equally spaced despite the difference in the starting and ending points of each field of the frame. All of this is taken care of by special sync pulses to be described later.

Thus, the pulses related to the control of the beam's vertical motion are called the *vertical sync* pulses, derived from the received signal. The blanking of the electron beam during vertical retrace is the function of the *vertical blanking* pulse, also derived from the received signal. The equalization of the difference in timing created by the half lines in each field is taken care of by *equalizing* pulses. All of these control pulses will now be explained.

The Vertical Blanking Pulse

We have learned that at the completion of a horizontal scanning line, there occurs a horizontal blanking interval during which the tube is "blacked out." The horizontal retrace occurs during this period. Hence, it does not appear as a visible line on the screen.



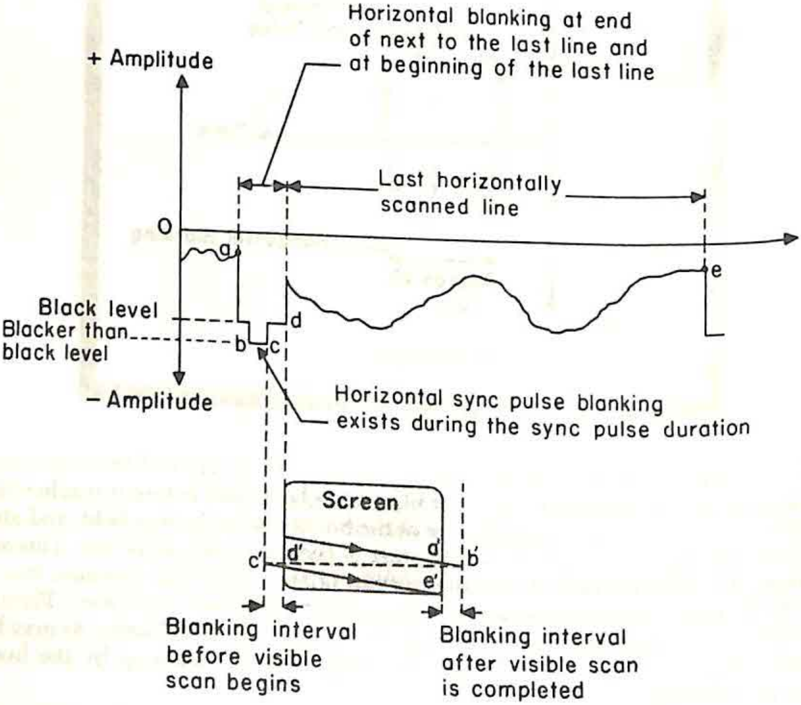
To be entirely correct in our statement, we show the duration of the horizontal blanking period as it really exists. It blanks the beam just before it reaches the limit of its travel under the influence of the horizontal deflection field, and also blanks the beam for a period at the start of the next horizontal line. This accounts for the fact that the visible portion of the horizontal scanning line is only 53.5 μsec, whereas the actual *horizontal line interval* is 63.5 μsec. Picture information is transmitted only during the time period of 53.5 μsec. As may be seen, 10 μsec of the full horizontal scanning time are taken up by the horizontal blanking.

The same action occurs with the vertical trace and retrace. Theoretically, when the last horizontal line of a field has been scanned, and the vertical retrace is supposed to start, the beam is blanked out by the vertical blanking pulse. This gives the beam the opportunity to return to the top of the tube screen without producing visible retrace lines.

The Vertical Blanking Pulse (cont'd)

One of the factors we learned was that the last scanned line in a field may be a whole line or a half line. To explain the action taking place under the influence of the vertical sweep control voltages, we may select either of these fields as an example. Arbitrarily, we choose the field which ends in a whole horizontal line. Here is the waveform representation of this condition.

Point *a* is the beginning of the horizontal blanking pulse for the next to the last line scanned. Points *b-c* represent the horizontal sync pulse and *d* is the end of the horizontal blanking period. Picture information is transmitted until point *e*. This point corresponds to the end of the field, and can be considered as the starting point for the vertical blanking pulse for the field in question.

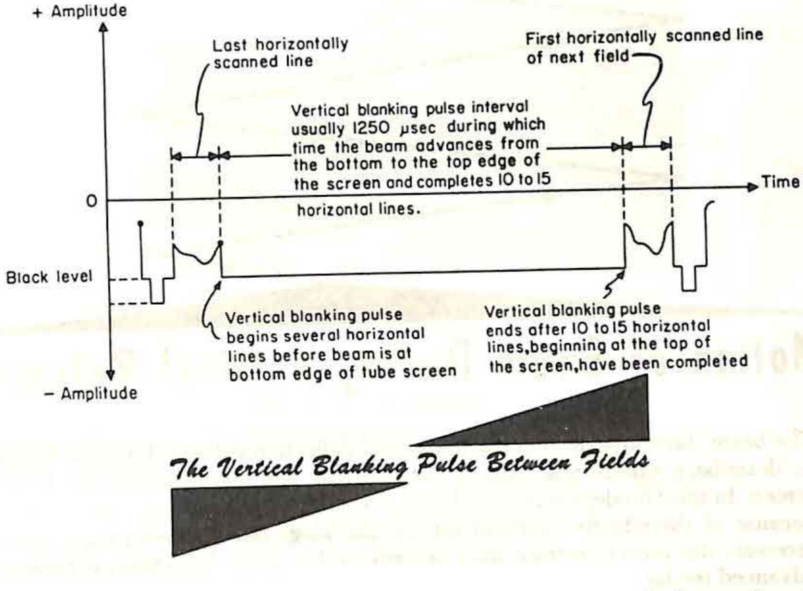

Horizontal blanking at end of next to the last line and at beginning of the last line
+ Amplitude
Last horizontally scanned line
O
a
e
Black level
Blacker than black level
b
c
d
– Amplitude
Horizontal sync pulse blanking exists during the sync pulse duration
Screen
d'
d'
c'
b'
e'
Blanking interval before visible scan begins
Blanking interval after visible scan is completed

The last full line in a field

The Vertical Blanking Pulse (cont'd)

Actually, point *e* is the start of the vertical retrace period, and the vertical blanking interval may start earlier than the completion of the last horizontal line. For the moment we may consider that the start of vertical blanking coincides with the end of the last line.

If we show the presence of the vertical blanking pulse in relation to the end of one field and the beginning of the next—that is, the completion of the bottom line of one field and the first line of the next field—we have this:


+ Amplitude
Last horizontally scanned line
First horizontally scanned line of next field
Vertical blanking pulse interval usually 1250 μsec during which time the beam advances from the bottom to the top edge of the screen and completes 10 to 15 horizontal lines.
Time
0
Black level
Vertical blanking pulse begins several horizontal lines before beam is at bottom edge of tube screen
Vertical blanking pulse ends after 10 to 15 horizontal lines, beginning at the top of the screen, have been completed
− Amplitude

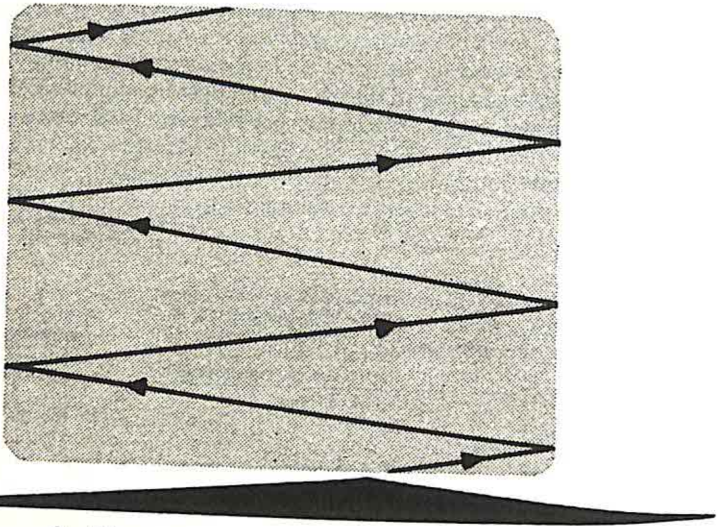
The Vertical Blanking Pulse Between Fields

The blanking pulse interval allowed by FCC regulations can be from a low of 833 μsec to a maximum of 1330 μsec. The tolerance is allowed because all signal generating equipment must be permitted some frequency variation. Although we speak here in terms of time duration, this term has its equivalent in frequency. An average period for the vertical pulse is about 1250 μsec. The shorter the pulse duration (within the limits stated), the greater the coincidence between its starting time and the end of the last horizontal line. Likewise, its "unblanking" approaches coincidence more closely with the start of the first horizontal line in the next field.

The amplitude of the vertical blanking pulse is the same as that of the horizontal blanking pulse. Hence, the tube is driven into the "black" region and the screen does not show the beam motion.

Vertical Retrace

It might be well to repeat that the motion of the beam during vertical retrace within the vertical blanking time is *not* a single surge upward in a straight line.



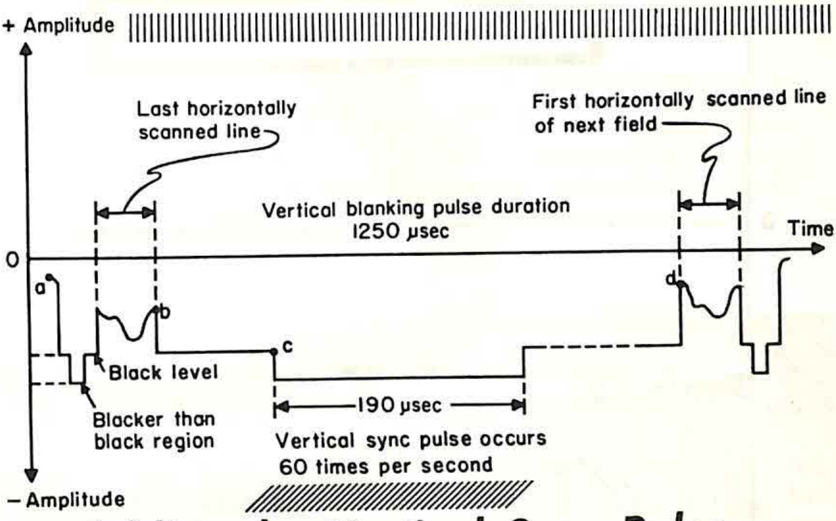
Motion of Beam During Vertical Retrace

The beam starts upward, but the horizontal deflection voltages force the beam to describe a side-to-side motion between the left and right edges of the screen. In most modern receivers this motion cannot be followed on the screen because of the effective vertical retrace blanking. But in some of the older receivers the vertical retrace lines become visible if the brightness control is advanced too far.

The production of vertical retrace lines is the result of improper grid bias on the picture tube. Normally, the retrace lines are invisible since they occur during the vertical blanking period. Since this represents the so-called black area of the picture tube, the retrace lines occur during the time that the picture tube is cut off. However, it frequently happens that the bias on the picture tube is not large enough. This can be caused by some component in the grid-cathode circuit becoming defective or by having the brightness control on the television receiver set for excessive brightness. In either case the retrace lines can become visible and the familiar back and forth motion of the picture tube beam can be seen as it moves from the bottom of the picture to the top. As explained later, special circuits have been designed to eliminate this sometimes annoying effect.

The Vertical Sync Pulse

The vertical sync pulse uses the vertical blanking pulse for its pedestal, just as the horizontal sync pulse rides on top of the horizontal blanking pulse. Once during every field the vertical sweep oscillator is fed a series of six successive triggering pulses which have the effect of a single 190-μsec pulse. The level of these pulses is the same as the blacker-than-black horizontal sync pulses.


+ Amplitude
Last horizontally scanned line
First horizontally scanned line of next field
Vertical blanking pulse duration 1250 μsec
Time
0
a
b
c
d
Black level
Blacker than black region
190 μsec
Vertical sync pulse occurs 60 times per second
– Amplitude

Adding the Vertical Sync Pulse to the Vertical Blanking Pulse.

This illustration shows the overall duration rather than the technical representation of the pulse; the discrepancy will be dealt with later. We might mention, however, that it has to do with the omission of the pulses required to maintain horizontal synchronization during the vertical sync pulse interval.

Another point of interest is the location of the leading edge *c* of the sync pulse relative to the leading edge *b* of the blanking pulse. It is shown as appearing some time after the start of the blanking pulse. Bearing in mind that the blanking pulse duration may vary somewhat, it is important to remember that the moment of triggering the vertical sweep oscillator remains fixed at the transmitter, regardless of the duration of the vertical blanking pulse. This is true for both fields of each frame.

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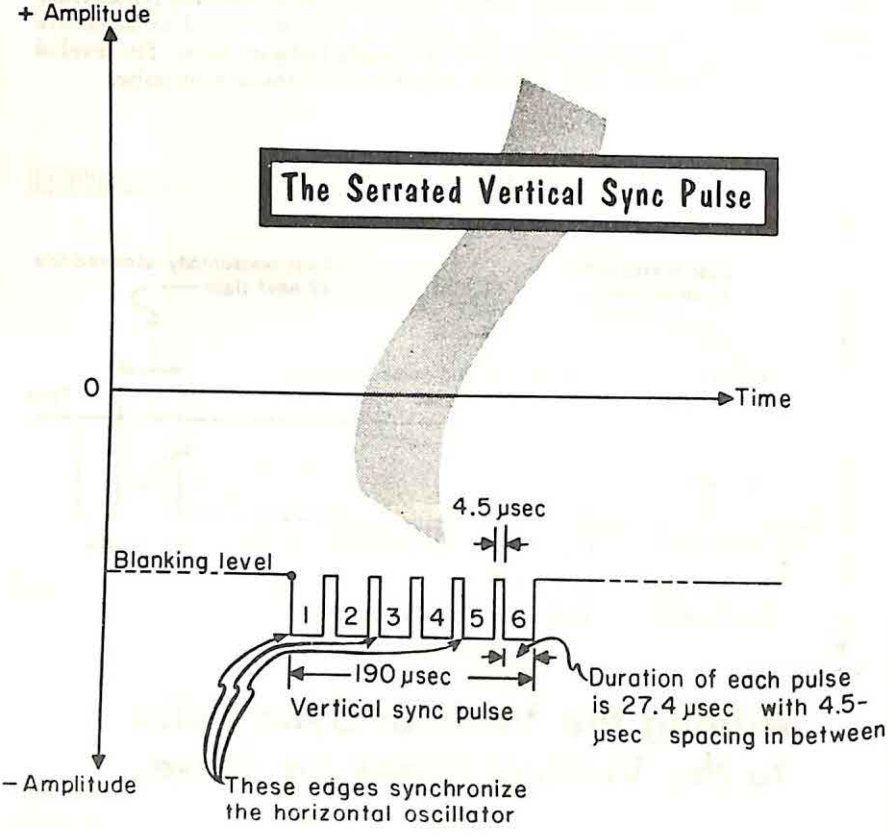
The Serrations in the Vertical Sync Pulse


+ Amplitude
The Serrated Vertical Sync Pulse
0
Time
4.5 µsec
Blanking level
1
2
3
4
5
6
190 µsec
Vertical sync pulse
Duration of each pulse is 27.4 µsec with 4.5-µsec spacing in between
− Amplitude
These edges synchronize the horizontal oscillator

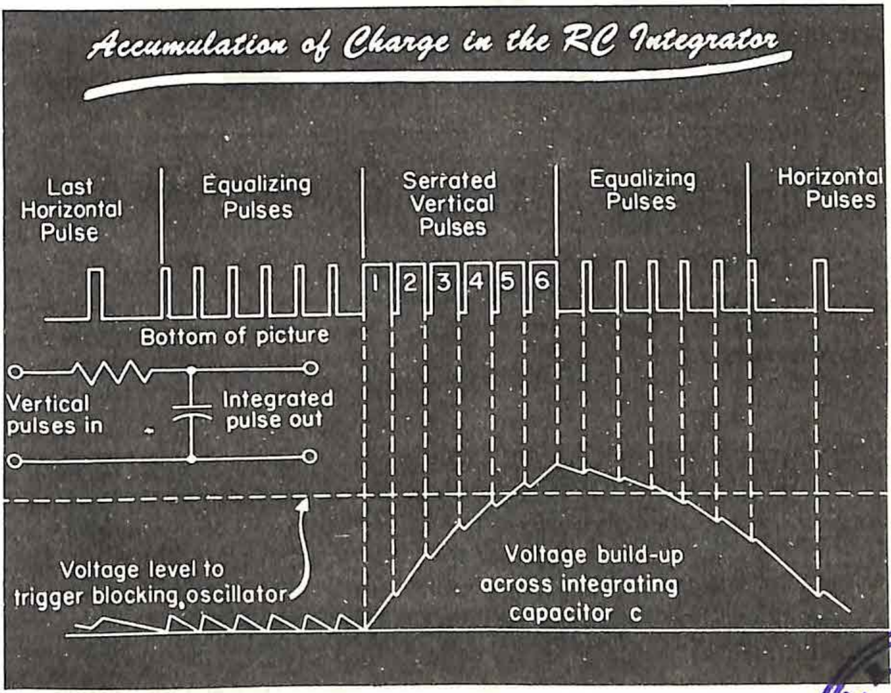
Continuous horizontal synchronization during the vertical sweep interval requires that the shape of the vertical sync pulse be modified. Its overall time-duration is held at 190 μsec, but to provide synchronizing pulses for the horizontal sweep oscillator the vertical pulse is divided into six equal pulses, each slightly more than 27 μsec in duration. A better way to describe this modification of the vertical sync pulse is to say that it is *serrated*.

These notches or serrations serve two functions. As six pulses which follow each other in comparatively rapid succession, they ultimately act on the vertical sweep oscillator as a single triggering pulse. This comes about as the result of another action called "integration" which will be explained shortly.

The Serrations in the Vertical Sync Pulse (cont'd)

These same serrations provide alternate pulses which control the horizontal sweep oscillator frequency. The alternate pulses are produced when the vertical pulse is divided into 6 equal parts each having a time duration equal to half a horizontal line. The leading edges of pulses 1, 3, and 5 synchronize the horizontal oscillator during the vertical retrace period when the field ends in a complete horizontal line. With each serrated pulse having a duration of 27.4 μsec, and with the spacing between serrations being 4.44 μsec, each pair of pulses corresponds to the time of a horizontal line, i.e., $(2 \times 27.4) + (2 \times 4.44)$, approximately 63.5 μsec.

In view of what follows later in this book, it is well to call attention to certain conditions which may not have been indicated by the time intervals of the vertical sync pulse serrations. Note that the duration of the individual pulses is long compared with the interval between them. This permits the use of these pulses to accumulate a charge in a capacitor until it reaches the level required to trigger the vertical sweep oscillator.



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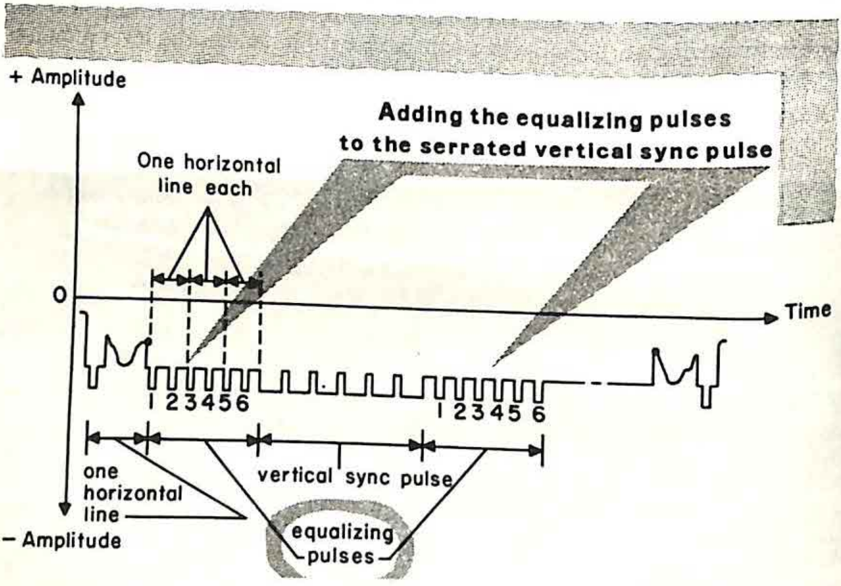
The Equalizing Pulses

Although we have seen how the vertical sync pulse is serrated to provide signals for horizontal synchronization during the vertical sync pulse interval, we must still consider the remainder of the time embraced by the vertical blanking interval. Somehow horizontal synchronization must be maintained during the entire vertical blanking interval for each field.

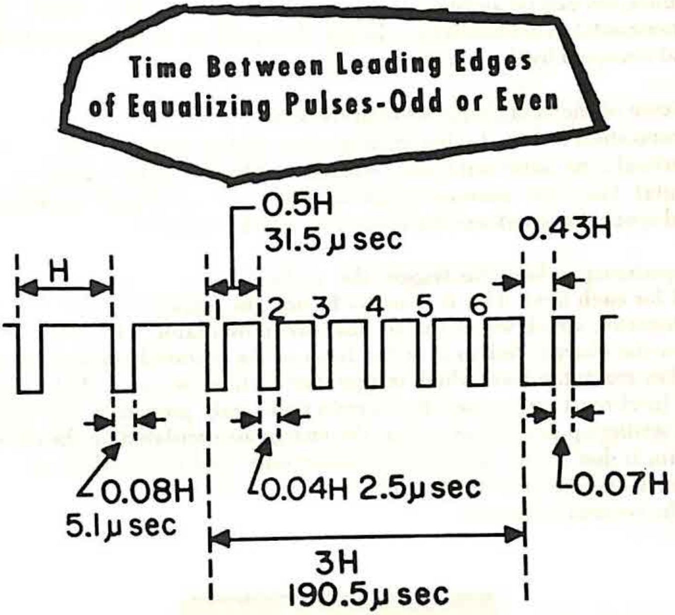
To achieve this synchronization, two sets of six pulses each are added, one set of six appearing before the start of the vertical sync pulse, and one set of six appearing after the conclusion of the vertical sync pulse interval. Later on we will show additional pulses, but for the present we will speak about these two sets of six pulses each.



These pulses are called *equalizing* pulses. Although they are shown for the one field which ends in a whole horizontal line, their accurate picturization would be only slightly different for the other field. Therefore, the following general comments are applicable to the equalizing pulses used for both fields of a frame.

One other point must be made. While the equalizing pulses appear among the signal waveforms embraced by the vertical retrace interval, they also are applied to the horizontal synchronizing system during the vertical retrace period.

The Equalizing Pulses (cont'd)



Six equalizing pulses appear between the start of the vertical blanking period and the start of the vertical sync pulse, and six more follow the vertical sync pulse. But unlike the serrations of the vertical sync pulse, the equalizing pulses are of short duration and have comparatively long intervals between them.

Each equalizing pulse has a duration of slightly more than 2.5 µsec and an interval between of slightly more than 29 µsec. From the leading edge of one pulse to the other the interval is substantially 31.5 µsec or equal to a half horizontal line. Therefore, two such pulses amount in time to a whole horizontal line.

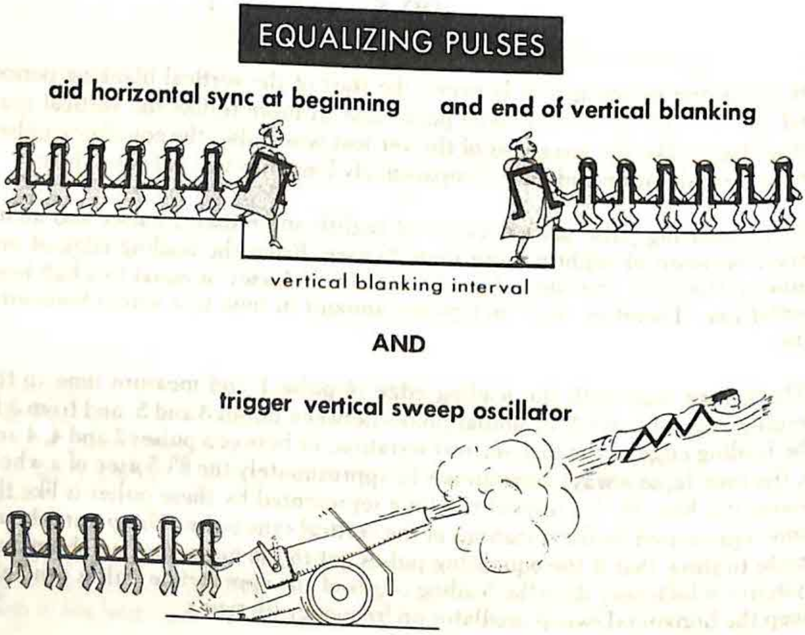
Whether we start with the leading edge of pulse 1 and measure time to the leading edge of pulse 3, or similar points between pulses 3 and 5, and from 5 to the leading edge of the first vertical serration, or between pulses 2 and 4, 4 and 6, the time lapse always corresponds to approximately the 63.5 µsec of a whole horizontal line. In this respect the time represented by these pulses is like the time represented by the serrations of the vertical sync pulse. This point is being made to show that if the equalizing pulses get to the horizontal synchronizing system—which they do—the leading edges of the appropriate pulses can help keep the horizontal sweep oscillator on frequency (in sync).

Functions of the Equalizing Pulses

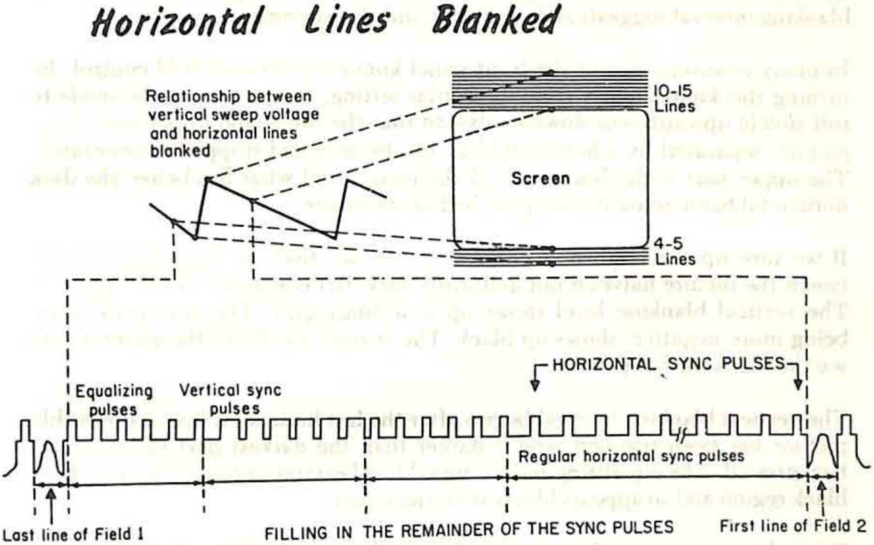
Two functions can be ascribed to the equalizing pulses. First of all, they perform horizontal synchronization during that portion of the vertical blanking interval occupied by the equalizing pulses.

In the case of the field that ends with the whole horizontal line, the horizontal synchronization is done by the leading edges of the odd numbered equalizing and vertical sync pulse serrations, whereas in the field which ends with a half horizontal line, the leading edges of the even-numbered equalizing and vertical sync pulses perform the horizontal synchronization.

The equalizing pulses also trigger the vertical sweep oscillator at the same instant for each field. This is done by having the equalizing pulses "prepare" the *integrator*, which serves the vertical sweep oscillator. The integrator accumulates the charges fed to it in the form of the serrated vertical sync pulses until they reach the level which triggers the vertical sweep oscillator. The triggering level must be reached at a certain time, and "preparing" the integrator means setting up conditions so that the charge accumulated on the integrating capacitor is due to the vertical sync pulses only, and to no other pulses which may reach the integrator. The full meaning of this will be clear when we explain the vertical integrator.


EQUALIZING PULSES
aid horizontal sync at beginning
and end of vertical blanking
vertical blanking interval
AND
trigger vertical sweep oscillator

The Horizontal Sync Pulses During Vertical Retrace



The time interval embraced by the six equalizing pulses *ahead* of the vertical sync pulse, and the six equalizing pulses *after* the sync pulse amounts to approximately 3 x 190 μsec or 570 μsec. With 63.5 μsec required for each horizontal line this time-lapse totals about 9 lines. But we know that the vertical retrace interval in practice amounts to about 1160 μsec. This leaves about 9.5 horizontal lines of time within the vertical retrace interval for which we have not shown any means for horizontal synchronization.

Horizontal synchronization is available in the form of a train of regular horizontal sync pulses which follow the second set of equalizing pulses. The number of these horizontal sync pulses which fill out the vertical retrace interval depends on the time allowed for the latter. Because of the tolerance allowed in the system, there may be as few as 9 such pulses, and there may be as many as 13. The exact figure is unimportant, as long as we understand that these pulses continue keeping the horizontal sweep oscillator on frequency while the beam is climbing its zig-zag path towards the top of the tube screen.

It is interesting to note that, in practice, the vertical blanking interval is sufficiently long so that it blanks out about 10–15 horizontal lines at the top of the screen and about 4–5 lines at the bottom of the screen. Even so, the vertical and horizontal synchronization is essential to proper interlacing, maximum resolution, and high stability.

A Simple Experiment

The explanation we have just given of the events occurring during the vertical blanking interval suggests an interesting, simple experiment.

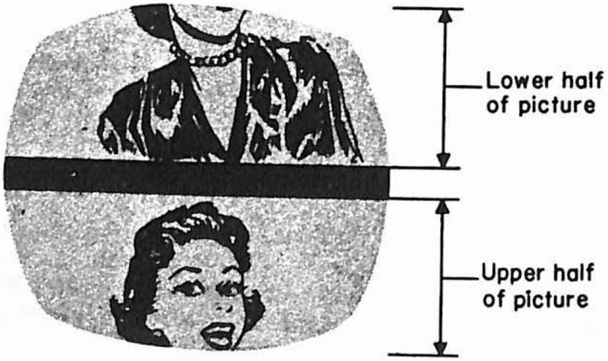
In many receivers, one of the front panel knobs is a *vertical hold* control. By turning this knob slightly from its regular setting, the picture can be made to roll *slowly* upwards—or downwards—so that the lower and upper half of the picture, separated by a horizontal bar, can be seen and stopped momentarily. The upper part is the lower half of the image, and what lies below the dark horizontal bar is actually the upper half of the image.

If we turn up the brightness control we can see that the horizontal bar between the picture halves is not uniformly dark, but contains a definite pattern. The vertical blanking level shows up as a dingy gray. The sync peak level, being more negative, shows up black. The sharper the focus the easier it is to see the blanking-bar pattern.

The vertical blanking interval begins after the last horizontal line of the visible picture has been scanned, and is darker than the darkest part of the image background. The equalizing pulses' signal level extends into the blacker-than-black region and so appears blackest on the screen.

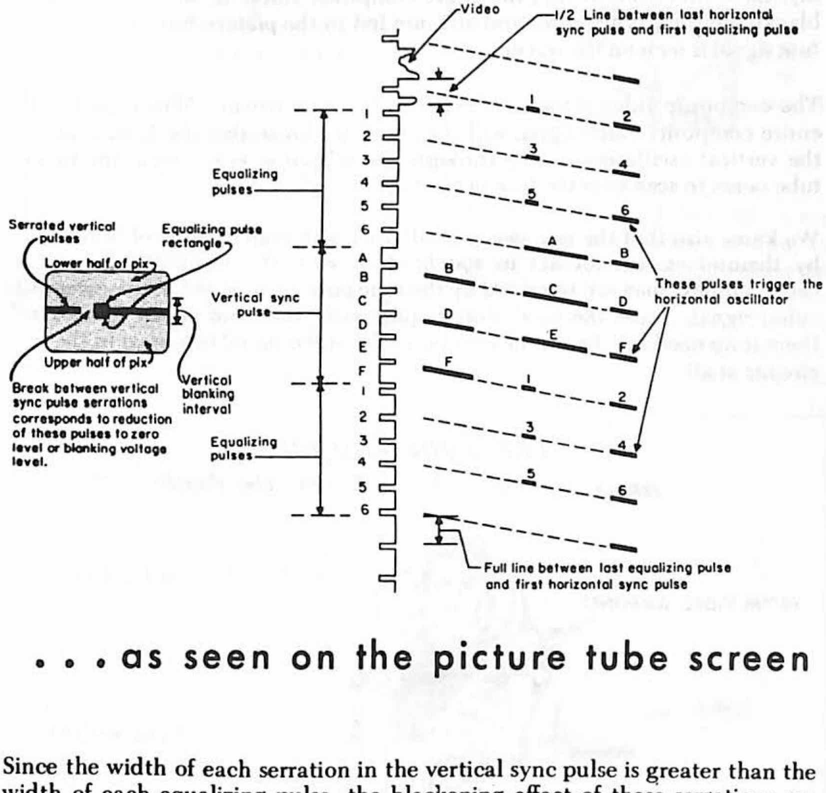
Since there are six equalizing pulses before the arrival of the serrated vertical sync pulse, the distance down from the top of the "hammer" represents the depth of three horizontal lines. Since the equalizing pulses occur at half-line intervals, the six equalizing pulses tick off three horizontal sweeps of the scanning beam.

The result of a slight readjustment of the vertical hold control



A Simple Experiment (cont'd)

SYNC PULSES . . .


Video
1/2 Line between last horizontal sync pulse and first equalizing pulse
Equalizing pulses
Serrated vertical pulses
Equalizing pulse rectangle
Lower half of pix
Vertical sync pulse
Upper half of pix
Vertical blanking interval
Break between vertical sync pulse serrations corresponds to reduction of these pulses to zero level or blanking voltage level.
Equalizing pulses
1
2
3
4
5
6
A
B
C
D
E
F
1
2
3
4
5
6
These pulses trigger the horizontal oscillator
Full line between last equalizing pulse and first horizontal sync pulse

. . . as seen on the picture tube screen

Since the width of each serration in the vertical sync pulse is greater than the width of each equalizing pulse, the blackening effect of these serrations occupies a greater width. As a matter of fact, each of these serrations occupies almost the entire width of half a line, with just a small break where the signal moves to the blanking level. The brighter effect of this small break is shown in the diagram. With the arrival of the next serration, the remainder of the horizontal line after the break is again black, and extends to the right-hand end of the screen.

When the last of the vertical serrations has passed, a second set of equalizing pulses follows. We should then expect the small black rectangle to appear underneath the broken horizontal bar of the serrations, as indeed it does.

Processing the Sync Signals

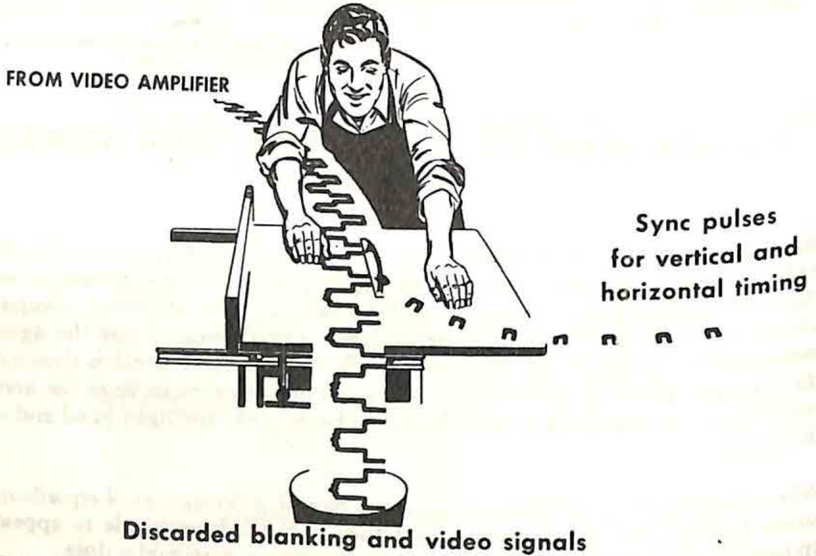
We already know the picture tube converts the *picture part* of the composite video signal into light and dark tones on the face of its screen. The blanking signals between picture information intervals, both horizontal and vertical, drive the picture tube to cutoff and make the retrace lines invisible. We can say, then, that even though the entire composite video signal—picture signal, blanking pulses, sync pulses and all—are fed to the picture tube, only the *picture* signal is seen on the screen.

The composite video signal is *also* fed to the sync circuits. Which part of the entire composite video signal will they use? We know that the horizontal and the vertical oscillators, acting through the deflection yoke, cause the picture tube beam to scan over the face of the tube.

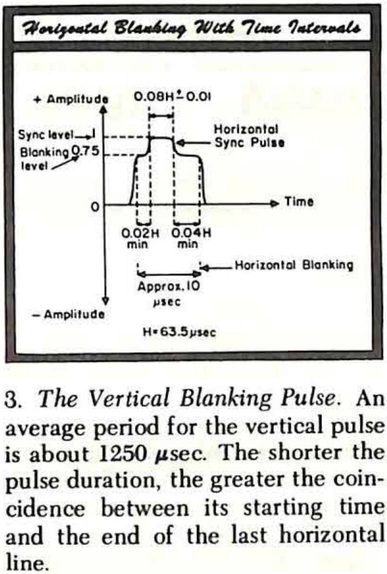
We know also that the two sweep oscillators, although capable of functioning by themselves, cannot act in *synchronism* with the transmitting station's camera unless they are triggered by the sync pulses contained in the composite video signal. Since the oscillators require only the sync pulses for control, there is no need for the rest of the composite video signal to appear in the sync circuits at all.

The Sync Clipper

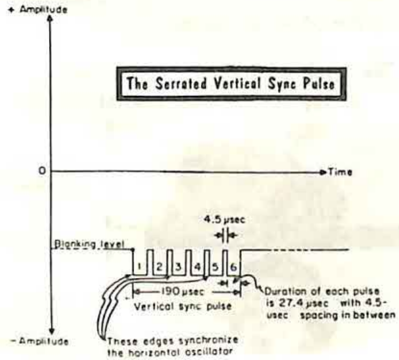
removes sync pulses from composite video signal

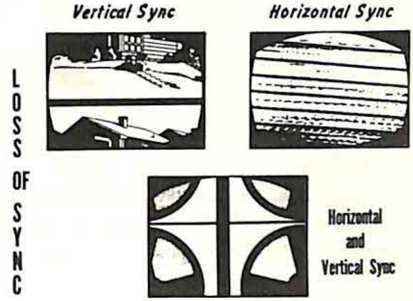

FROM VIDEO AMPLIFIER
Sync pulses for vertical and horizontal timing
Discarded blanking and video signals

1. *Synchronization of the Picture* involves the accurate control of the horizontal and vertical sweep oscillators, the two blanking actions, and the correct timing between the start of the horizontal sweep and retrace. It also involves the start of the vertical sweep and retrace in the picture tube and the camera tube.

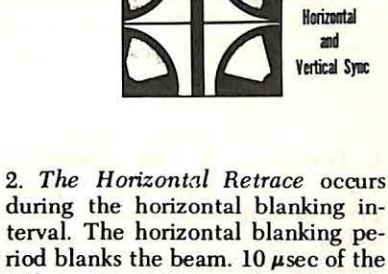

Horizontal Blanking With Time Intervals

3. *The Vertical Blanking Pulse.* An average period for the vertical pulse is about 1250 µsec. The shorter the pulse duration, the greater the coincidence between its starting time and the end of the last horizontal line.

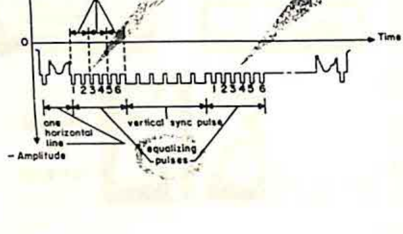

+ Amplitude
The Serrated Vertical Sync Pulse
0
Time
4.5 µsec
Blanking level
1
2
3
4
5
6
190 µsec
Vertical sync pulse
Duration of each pulse is 27.4 µsec with 4.5-usec spacing in between
– Amplitude
These edges synchronize the horizontal oscillator



2. *The Horizontal Retrace* occurs during the horizontal blanking interval. The horizontal blanking period blanks the beam. 10 µsec of the full· horizontal scanning time is taken up by the horizontal blanking. This accounts for the fact that the visible portion of the horizontal scanning line is only 53 µsec.

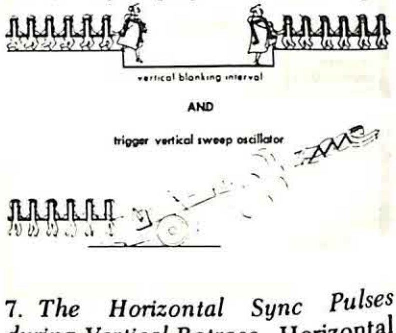

The Vertical Blanking Pulse Between Fields
+ Amplitude
Last horizontally scanned line
First horizontally scanned line of next field
Vertical blanking pulse interval usually 1250 µsec during which time the beam advances from the bottom to the top edge of the screen and completes 10 to 15 horizontal lines.
0
Time
Black level
Vertical blanking pulse begins several horizontal lines before beam is at bottom edge of tube screen
Vertical blanking pulse ends after 10 to 15 horizontal lines, beginning at the top of the screen, have been completed
– Amplitude

4. *The Serrations in the Vertical Sync Pulse.* The overall time-duration of the vertical sync pulse is held at 190 µsec. To provide sync pulses for the horizontal sweep oscillator the vertical pulse is divided into six equal pulses each slightly more than 27 µsec in duration. We say that the vertical pulse is serrated.

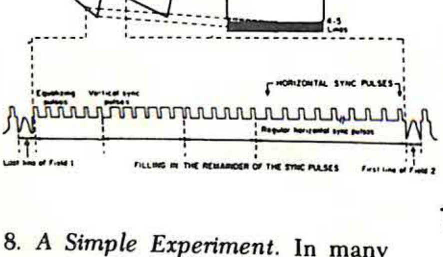


5. *The Equalizing Pulses.* The vertical sync pulse is serrated to provide signals for horizontal sync during the vertical sync pulse interval. To maintain horizontal sync during the vertical interval, for each field two sets of six pulses each are added, one set of six before the start, and one set of six after the conclusion of the vertical sync pulse interval.

6. *Functions of the Equalizing Pulses.* The equalizing pulses perform horizontal synchronization during the portion of the vertical blanking interval occupied by the equalizing pulses. The equalizing pulses also trigger the vertical sweep oscillator at the same instant for each field.


EQUALIZING PULSES
aid horizontal sync at beginning
and end of vertical blanking
vertical blanking interval
AND
trigger vertical sweep oscillator

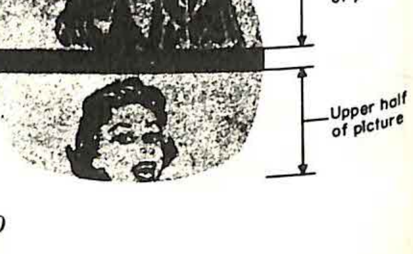
Horizontal Lines Blanked


Relationship between vertical sweep voltage and horizontal lines blanked
10-15 Lines
Screen
4-5 Lines
HORIZONTAL SYNC PULSES
Equalizing pulses
Vertical sync pulses
Regular horizontal sync pulses
Last line of Field 1
FILLING IN THE REMAINDER OF THE SYNC PULSES
First line of Field 2

7. *The Horizontal Sync Pulses during Vertical Retrace.* Horizontal synchronization is available in the form of a train of regular horizontal sync pulses which follows the second set of equalizing pulses. The number of these horizontal sync pulses which fill out the vertical retrace interval depends on the time allowed to the latter.

8. *A Simple Experiment.* In many receivers, one of the front panel knobs is a vertical hold control. By turning this knob slightly from its regular setting, the picture can be made to roll slowly upward—or downward. The upper part is the lower half of the image, and what lies below the dark horizontal bar is actually the upper half of the image.

The result of a slight readjustment of the vertical hold control



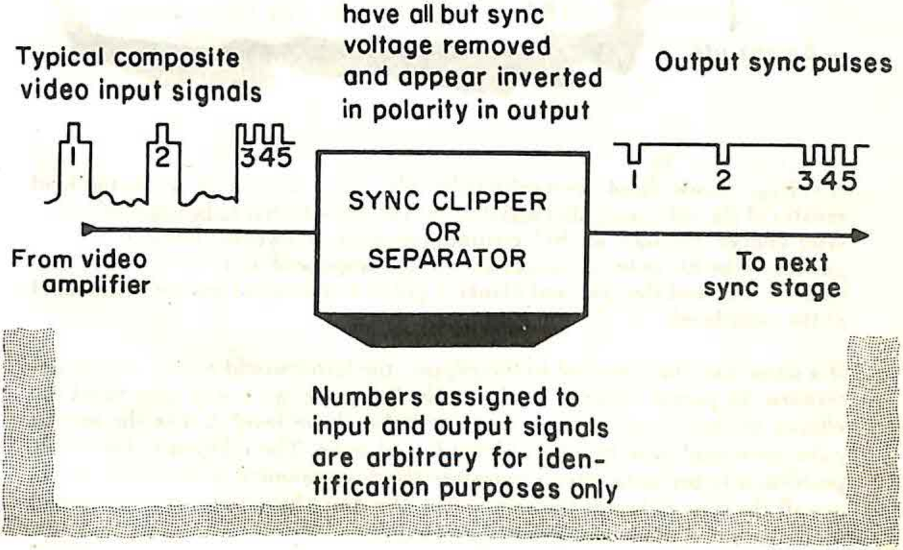
The Sync Clipper—or Separator

If only the sync pulses are needed in the sync circuits, there must be some arrangement which removes the *sync pulses* from the composite video signal, and discards the remainder of the signal. Such action is called sync clipping or sync separation.

The stage which performs this function is called the *sync clipper* or *sync separator* and the block diagram shows what its output signals look like for a typical input. The output signal is made up of the same sync pulses that were sitting on top of the pedestals of the input signal, but the pulses appearing in the output signal are *inverted*. This, of course, is the familiar *phase inversion* behavior of a single stage of amplification. The sync clipper also serves as an amplifier.

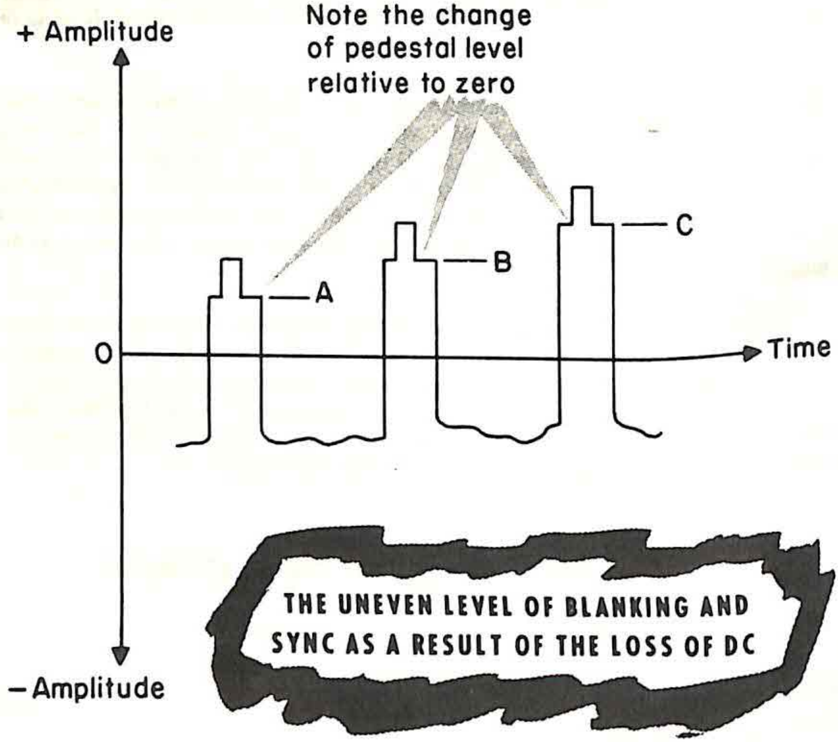
The sync clipper clips the sync peaks off the composite video signal in somewhat the same way as a gardener might clip the tops of a hedge. He establishes a line that he visualizes as the "clipping level," and clips down to that line but no further. We get all the sync pulses at the *same level* by establishing a "clipping level" in the stage. Coupling is usually arranged between the output circuit of the video amplifier and the input to the sync clipper.

The function of the Sync Clipper


Typical composite video input signals
have all but sync voltage removed and appear inverted in polarity in output
Output sync pulses
1
2
345
SYNC CLIPPER OR SEPARATOR
From video amplifier
To next sync stage
Numbers assigned to input and output signals are arbitrary for identification purposes only

9.12.05
12044
Library

Loss of DC Component



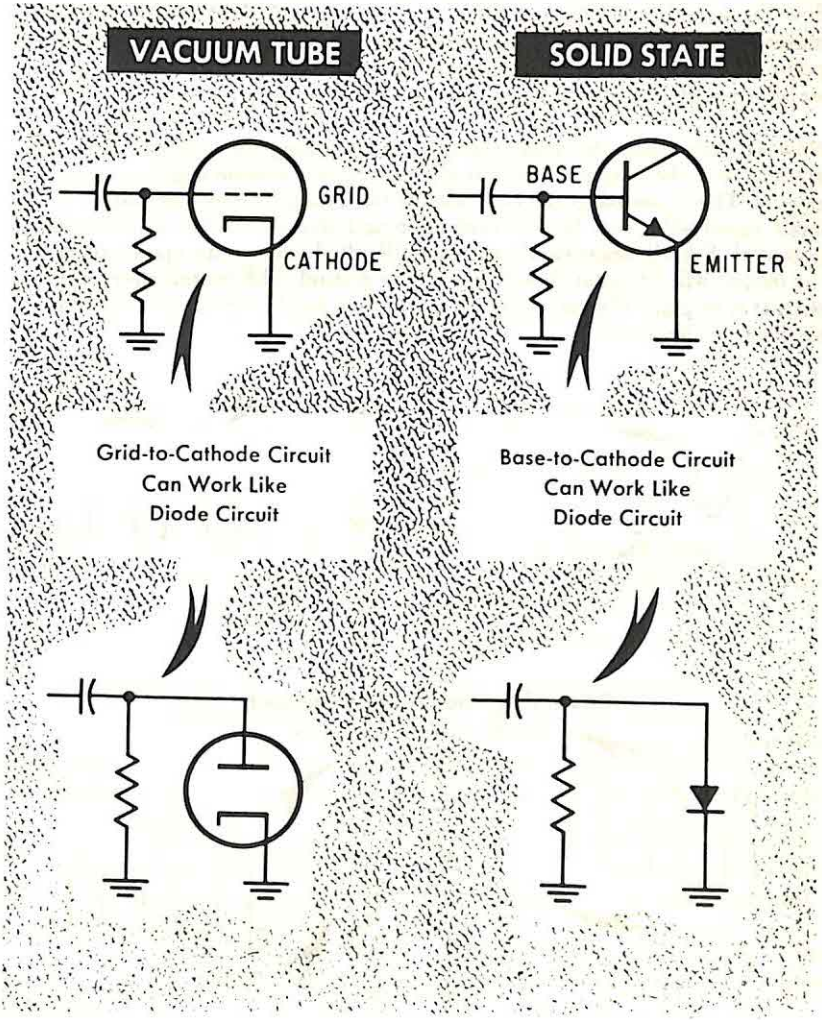
THE UNEVEN LEVEL OF BLANKING AND SYNC AS A RESULT OF THE LOSS OF DC

A voltage (made up of composite video plus dc) is developed across the load resistor of the video amplifier and it is this voltage which is to be coupled to the sync clipper through an RC coupling network. However, because the capacitor in the RC network blocks dc, the dc component of the composite video signal is lost, and the sync and blanking pulses in the signal are not maintained at the same level.

If a signal like this were fed to the clipper, the latter would not be able to determine the proper clipping level. For the first pulse, we would have to set the clipper so that it will remove the sync pulse above level A. For the second pulse we would have to set it at level B, and so on. The solution to the whole problem is to use some circuit to *restore the dc component* to the signal and so get all the sync pulses at the *same level.* We don't have to go very far to find such a circuit. A diode clamper will do the job.

Loss of DC Component (cont'd)

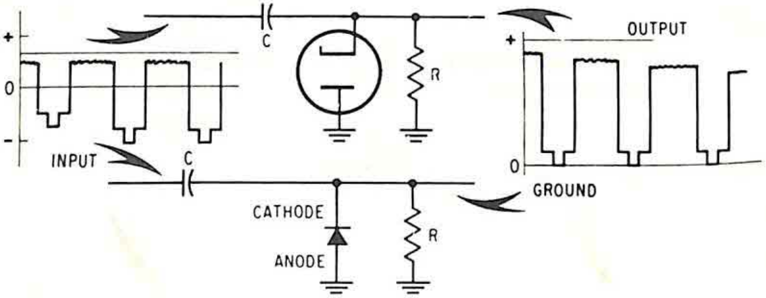
However, a separate diode is not required. Instead, the grid-cathode circuit of a vacuum tube or the base-emitter circuit of a transistor can be made to operate as a diode to accomplish clamping. To understand how that is possible, let's first analyze the operation of diode clampers.


VACUUM TUBE
SOLID STATE
GRID
CATHODE
BASE
EMITTER
Grid-to-Cathode Circuit Can Work Like Diode Circuit
Base-to-Cathode Circuit Can Work Like Diode Circuit

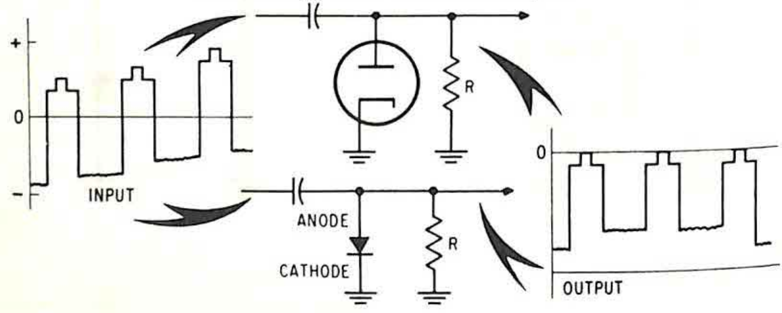
The Diode Clamper

When the anode of the vacuum tube or solid-state diode clamper is grounded, the result is called positive clamping. If the anode is made positive with respect to the cathode or the cathode is made negative with respect to the anode, current will flow through the diode. Thus in the grounded-plate diode clamper shown, the diode will act as an open circuit during the positive alternations of the input signal. The negative alternations will cause diode current to flow. At maximum negative alternation, there will be maximum current flow through the diode causing it to act as a virtual short circuit. Thus, the maximum negative swing of the input signal is effectively placed at ground potential. We can see from this that with the input signal shown, the output waveform will vary from ground to some positive value.

Now we can reverse the diode clamper by grounding the cathode. In the diagram shown, the output waveform will vary between some negative value and ground. This is caused by the fact that the maximum positive alternation of the input signal will cause heavy conduction and thus place the plate at ground potential. For all negative alternations, the diode acts as an open circuit and the output will be negative with respect to ground. The overall effect of these circuits is to place the sync peaks at a constant level so they can be processed by the sync clipper.



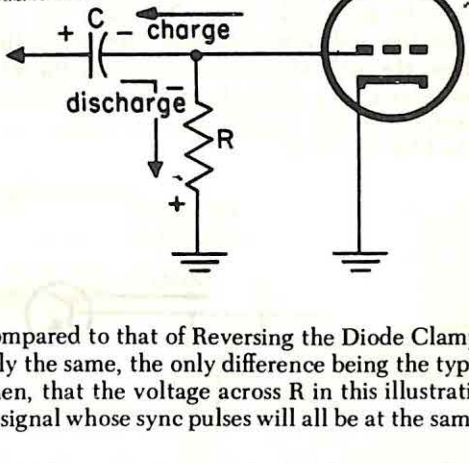
Reversing the Diode Clamper



Developing the Clipper Circuit (Grid Clamping)

From what we know about the behavior of a tube with one or more grids, we can say that the combination of control grid and cathode of such a tube could be used as a diode. If the signal applied to the control grid swings positive with respect to cathode, the grid draws current; when the signal swings negative, no current is drawn. This is exactly the way the diode works. What we can do, then, is to use the cathode and control grid of a triode or pentode as the diode for our clamper circuit.

USING THE CONTROL GRID AND CATHODE OF A TUBE AS A DIODE CLAMPER



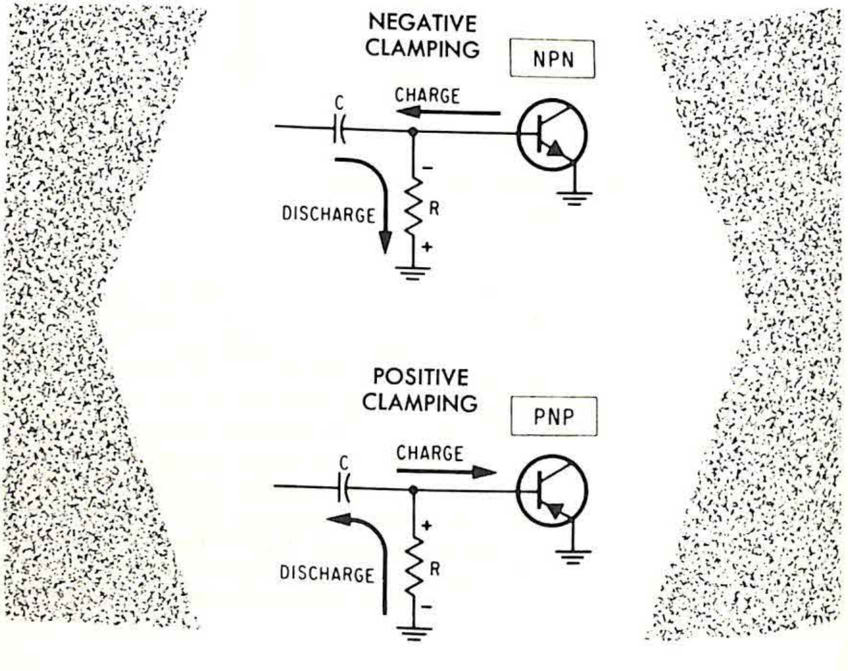
If this schematic is compared to that of Reversing the Diode Clamper, the two are found to be exactly the same, the only difference being the type of tube involved. It follows, then, that the voltage across R in this illustration will also be a composite video signal whose sync pulses will all be at the same level.

Fundamentally, this circuit operates on two separate operations. Initially, when any signal that is positive with respect to cathode is applied to the grid, the grid will draw current. As current is drawn by the grid, capacitor C acts as a short circuit to the charging current, and will charge approximately to the peak value of the applied voltage. After the applied voltage has passed its peak and begins to decline, the voltage necessary to keep the capacitor charged is no longer present and the capacitor begins to discharge through resistor R, developing a voltage on the grid side of the resistor that is negative with respect to ground. Since the discharge path is a higher resistance than the charge path, the discharge is slow, and there will still be some charge remaining when a new voltage pulse arrives, again driving the tube into conduction, and the cycle starts again. The overall result is to maintain a relatively stable dc bias voltage on the grid.

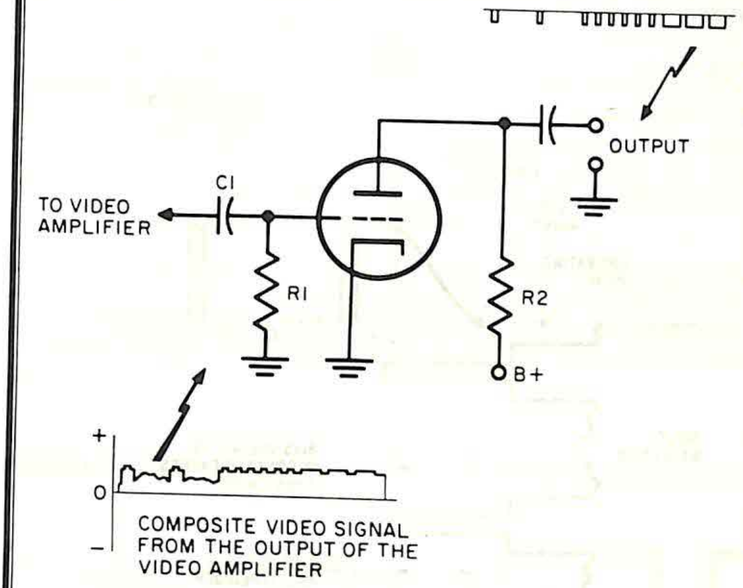
Developing the Clipper Circuit (Base Clamping)

The figure below shows how NPN transistors provide negative clamping and how PNP transistors provide positive clamping. Of course, transistors make both types of clamping possible because the emitter-to-base junction in each type transistor is reversed from NP in NPN transistors to PN in PNP transistors. Notice that it is the NPN transistor that provides negative clamping similar to that of the vacuum tube amplifier. When the P-base of the NPN transistor becomes positive with respect to the ground N-emitter, the emitter-base junction becomes forward biased and conducts heavily, providing a rapid charge path for the coupling capacitor. During the slow discharge path through the resistor, the P-base becomes negatively clamped, similar to the way it's done in vacuum-tube circuits.

On the other hand, the emitter-base junction of PNP transistors provides us with the opposite effects—positive clamping. Notice that the emitter-base junction of the transistor conducts only when the N-base becomes negative with respect to the grounded emitter. The capacitor charges through the N-base, to the emitter and then to ground. Now when the capacitor begins its discharge phase, the path is from ground through the resistor to the capacitor. Since this discharge path is much slower than the charge path through the NP transistor junction, the RC junction develops and couples a positive charge to the base of the PNP transistor.



Completing the Sync Clipper (Vacuum-Tube Type)


OUTPUT
C1
TO VIDEO AMPLIFIER
R1
R2
B+
+
0
–
COMPOSITE VIDEO SIGNAL FROM THE OUTPUT OF THE VIDEO AMPLIFIER

The Complete Sync Clipper

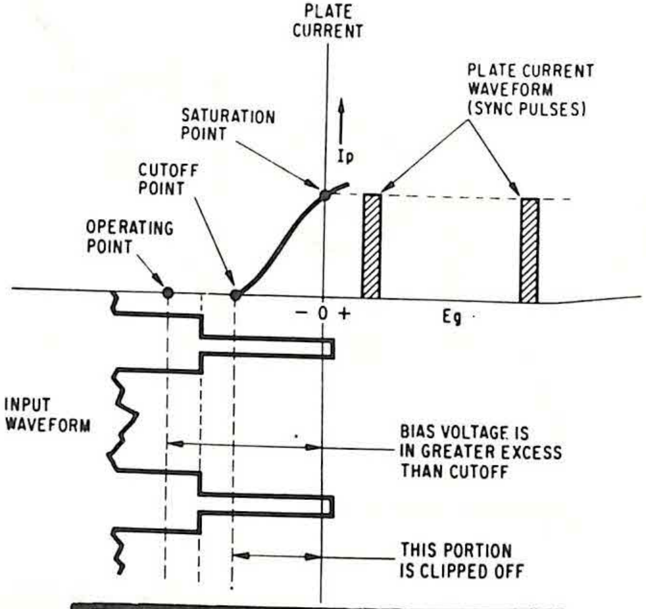
Now that we have seen how the combination of a tube's control grid and its cathode works, suppose we fill in the rest of the tube and its circuit.

If R1 (the same resistor as R in the schematic of the diode clamper) has a rather high value of resistance, the dc voltage across it will be correspondingly high, and the bias on the tube's control grid may be even more negative than cutoff. Assuming that this condition prevails, the plate current that flows through output load resistor R2 will have the waveshape illustrated on the next page.

Here we see how the tube's I_p-E_g characteristic curve can be used to show the waveform of the plate current in the sync clipper. The vertical dotted line is the bias voltage on the control grid, and since it is the average value of the composite video signal, the signal is shown varying around it. Because the bias voltage is more negative than cutoff, the dashed line is drawn to the *left* of the cutoff point.

Completing the Sync Clipper (Clipping Action)

We know that any part of the varying control grid signal which is *more negative* than cutoff will produce no plate current. In the diagram above, therefore, nothing to the left of the cutoff point appears as plate current, but the parts of the composite video signal to the right of cutoff do permit plate current flow.



The Behavior of the Plate Current of the Clipper-Amplifier

Note that only the *sync pulses* appear to the right of cutoff, so that the plate current waveform is made up of sync pulses only.

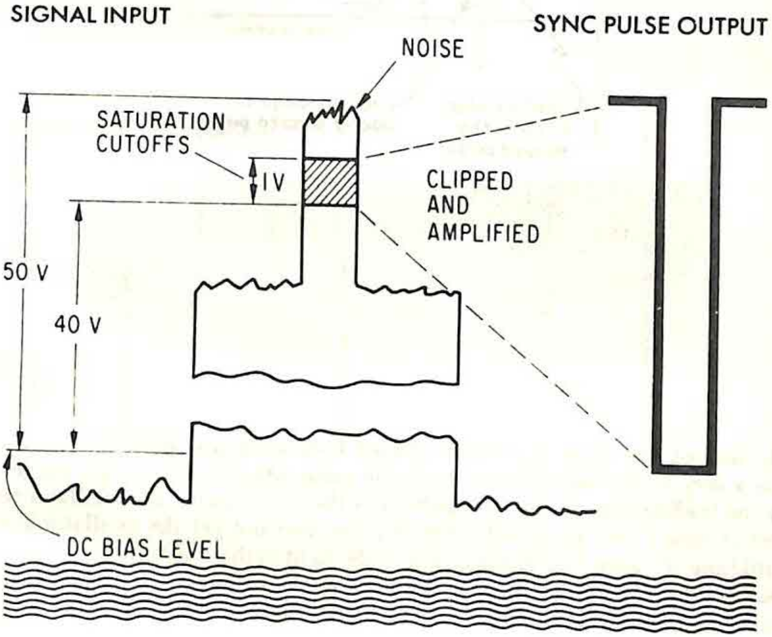
When plate current flows through plate resistor R2 in the schematic, the top of the resistor is *negative* with respect to the bottom end of the resistor. We can see, then, that the sync pulse peaks which were put on the grid as positive-going voltages become *negative*-going voltages across the load resistor R2.

Looking carefully at the input waveform again, you will notice that the sync pulses not only drive the tube out of cut off but also into saturation. At the saturation level the plate current levels off, not increasing any further even though the sync pulse voltage at the grid increases in value. Thus, the positive sync pulses at the plate represent an amplified slice from the middle of the sync pulses driving the grid.

Pulse Shaping and Amplifying

Essentially, the sync clipper-amplifier stage clips a thin slice of the sync pulse and then amplifies it by about 50 times. As you noticed in the previous diagram, the composite video signal negatively clamps the grid so that the signal operates mostly in the cutoff region. Actually, the signal input is about 50 V peak-to-peak, and about 40 V of that signal is below cutoff. Thus, when the input signal establishes the bias voltage, the signal will ride on the dc bias level that's about 40 V below cutoff. When the sync pulse arrives at the grid, the leading edge of the pulse rises to the cutoff level, quickly driving the tube into conduction. The transition from the cutoff to the saturation level is almost instantaneous, covering only about a 1-V range. In the saturation range, the tube draws grid current which, of course, helps to establish the negative clamping action. The tube continues to conduct for the duration of the sync pulse, and then, returns toward the cutoff level.

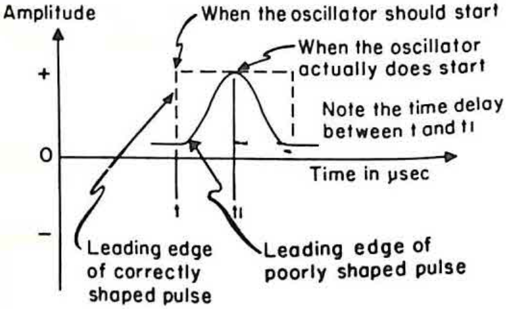
The clipped portion of the pulse is the only portion of the signal that is actually amplified. This thin slice of about 1 V, or less, essentially turns the tube on and off, causing the plate voltage to fall from its B+ value almost to ground-level voltage. The amplified pulse that results is about 50 V peak-to-peak.



Pulse Shape

One of the advantages of clipping the sync pulse this way is that we are able to amplify a portion of the sync pulse virtually free of noise that usually rides the peak and base levels of the signal. Another advantage is that we can develop a sync pulse that has sharp leading and trailing edges.

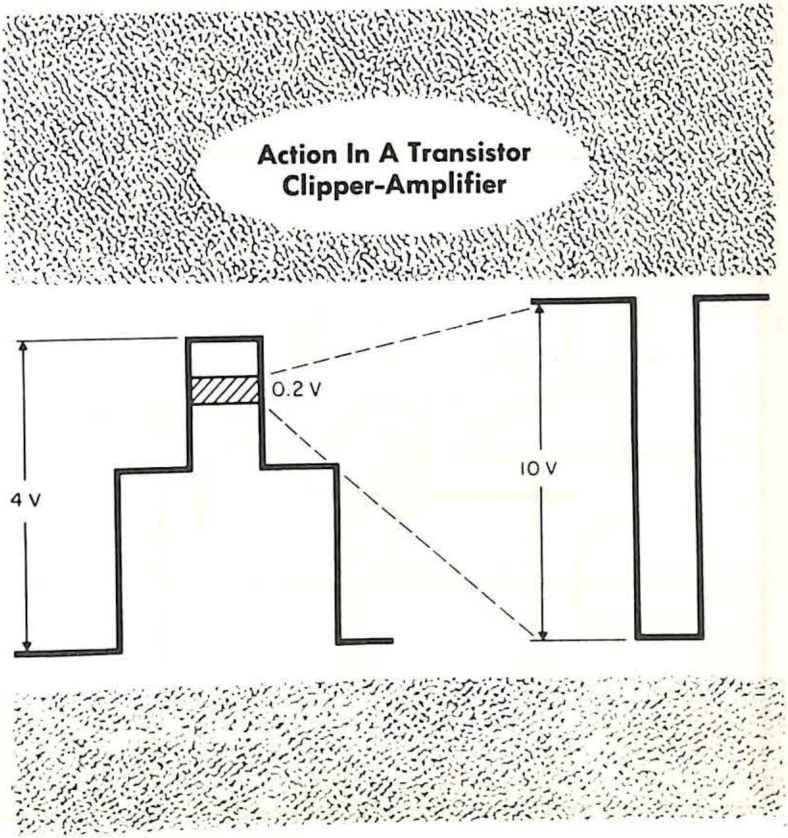
How a Badly Shaped Pulse May Cause Poor Syncing


Amplitude
+
0
−
When the oscillator should start
When the oscillator actually does start
Note the time delay between t and t1
Time in μsec
t
t1
Leading edge of correctly shaped pulse
Leading edge of poorly shaped pulse

The dashed line shows a properly shaped horizontal sync pulse and the solid line a very badly shaped horizontal sync pulse. Most oscillators are triggered by the leading edge of the sync pulse. For the square pulse, the oscillator triggers at time *t*. But the poorly shaped pulse does not get the oscillator going until time *t*1. Since time is advancing to the right in this illustration, we can see that the distorted pulse triggers the horizontal oscillator later than it is normally supposed to. The result is a picture that will tear.

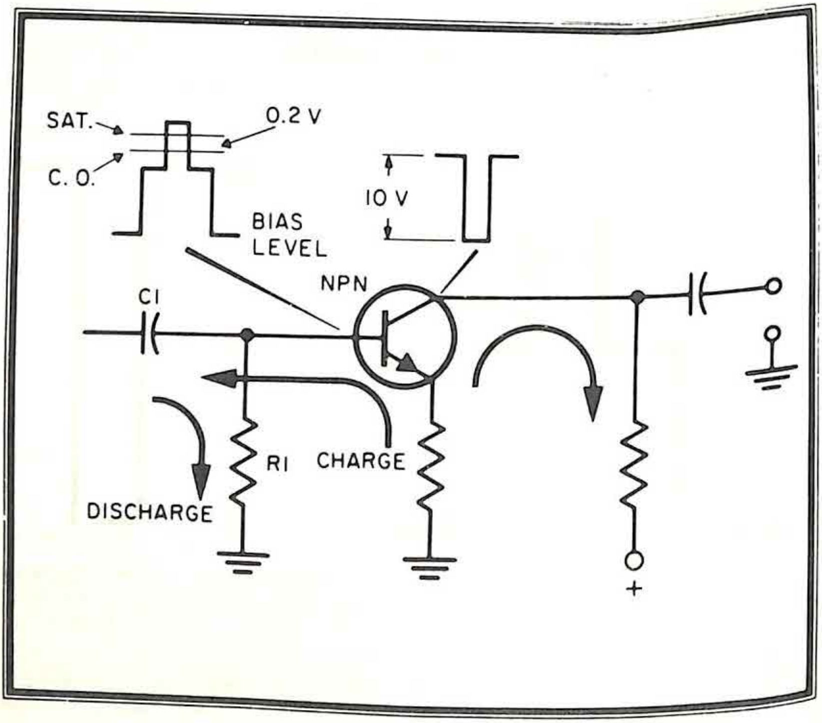
Transistor-Type Sync Clipper-Amplifier

Transistor-type sync circuits frequently use only one transistor to accomplish both sync clipping and amplifying. One major difference from the vacuum-tube type is that transistors will usually operate at much lower dc supply and signal-voltage levels. The highest dc voltage in many transistor circuits is usually about 12 V. With such low dc voltages, you can expect that the input and output signals are relatively small compared to those you encounter in vacuum-tube circuits. Below are typical values of voltage for the composite video signal at the base and collector of transistor sync circuit. Notice that the base signal is about 4 V peak-to-peak, from which the transistor clips only about 2/10 V from the sync pulse. This clipped portion of the sync pulse is amplified about fifty times to 10 V peak-to-peak at the collector. Now let's analyze how the transistor does this.


Action In A Transistor Clipper-Amplifier

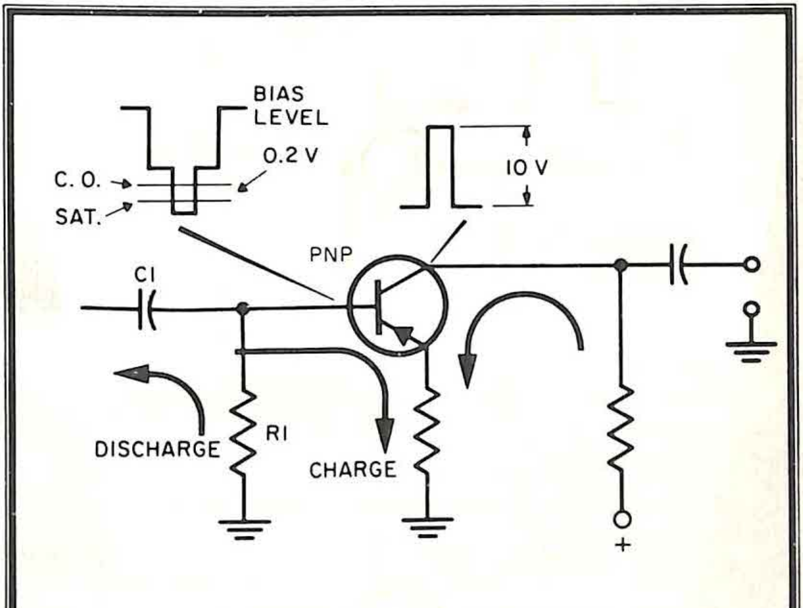
Transistor-Type Sync Clipper-Amplifier (cont'd)

Generally, sync clipper-amplifier circuits that use NPN transistors have a positive-going composite video signal driving the P-base. When the positive signal arrives at the base, the PN junction becomes forward biased and will cause the transistor to conduct heavily. Since only 2/10 V from the 4-V composite signal is required to drive the transistor from cutoff to saturation, the large, driving voltage causes the transistor to draw base current and charge capacitor C1. Since the forward biased emitter-to-base junction is a low resistance path, capacitor C1 charges rapidly and remains charged for the duration of the pulse. At the trailing edge of the pulse, the pulse swings in a negative direction, causing capacitor C1 to discharge through resistor R1. This discharge path through R1 develops a voltage drop that's negative at the base end of the resistor with respect to ground. As the trailing edge of the pulse swings in the negative direction, it quickly changes the operation of the transistor from saturation to cut-off. Thus, the transistor is essentially turned on and off for the period of the sync pulse. This on-off change in the collector causes the voltage to swing from about positive 10 V to almost ground potential. After the first few sync pulses, the slow discharge of C1 through R1 establishes a negative voltage that maintains the transistor deep into the cutoff region.



Transistor-Type Sync Clipper-Amplifier (cont'd)

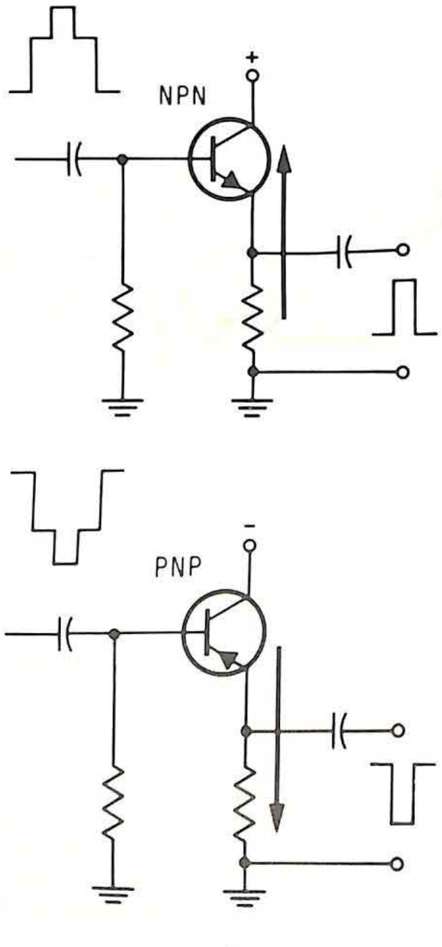
When the PNP transistor is used as the sync clipper-amplifier, you'll notice that a negative composite video signal is fed to the N-type base. You'll also notice that the negative signal develops a positive dc bias voltage at the base that cuts off the transistor until the negative sync tips arrive. The negative sync pulses forward biases the PN emitter-base junction of the PNP transistor into conduction, providing a rapid discharge path for C1. At its trailing edge, the sync pulse quickly swings positively, causing C1 to charge slowly through R1.



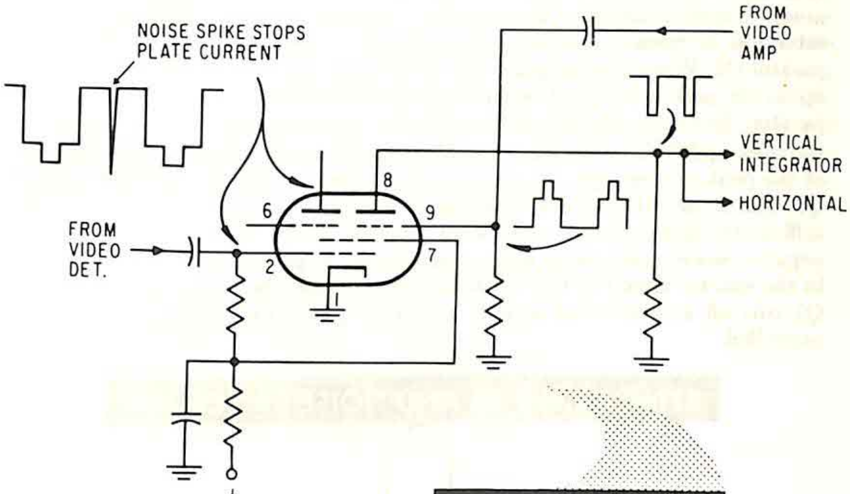
This slow charge path establishes a positive dc voltage at the N-base sufficient to drive the base deep into cutoff. When the PNP-type transistor is driven from cutoff to saturation, the pulses at the collector swing from a negative value to the ground potential, forming a series of positive-going sync pulses.

Transistor-Type Sync Clipper-Amplifier (Emitter Output)

Some transistor type sync clipper-amplifiers are designed to develop the sync pulses across the emitter resistor. This is done to appropriately match the output impedance and to develop output pulses that are in phase with the input pulses. Below are examples of NPN and PNP transistors providing an in-phase output from the emitter. Notice that the base-circuit configuration is essentially the same as the circuits you have just studied: positive signals are fed to the P-base of NPN transistors while negative signals are fed to the N-base of PNP transistors. When the transistors conduct, current flows through the emitter resistor in the direction shown by the solid arrow. Thus, the NPN transistor develops positive sync pulses across the emitter, while the PNP transistor develops negative sync pulses.



Gated-Sync Circuits with Noise Cancellation



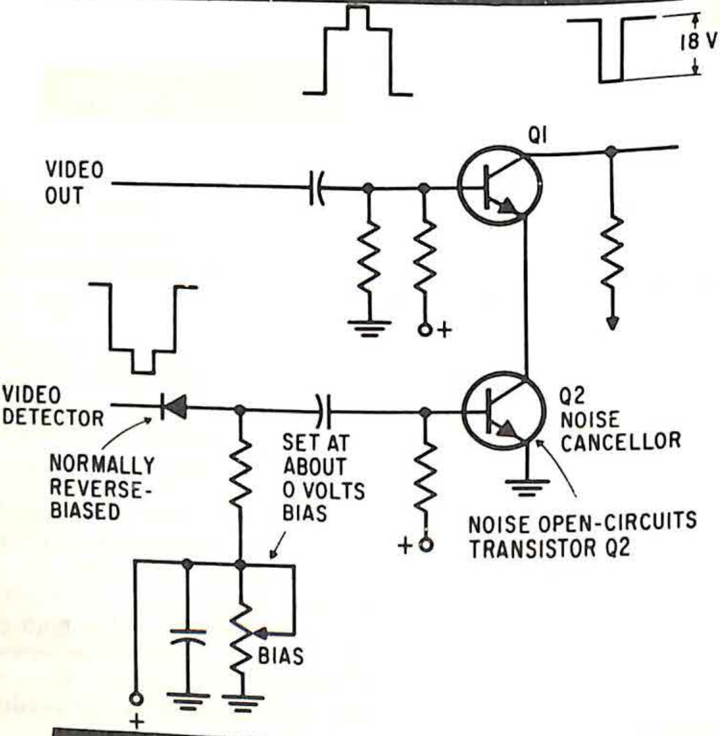
GATED SYNC CIRCUIT

One circuit that you'll encounter in a number of vacuum-tube type sync circuits is the gated-sync circuit, which combines sync separation, amplification, noise cancellation, and AGC. The circuit shown here uses a sharp cutoff twin pentode. But notice the unique feature about this tube. Both pentodes use the same control grid (pin 2) and screen grid (pin 7). Here's how it works. The bias level of grid 2 is set high enough so that the negative sync tips coupled to grid 2 have almost no effect on the tube's conduction. Grid 2 bias-level is not that positive, however, to prevent the higher value negative noise spikes to reduce current in both halves of the tube. Now let us examine grid 9, which is part of the sync clipper-amplifier section of the tube. The bias voltage on grid 9 is established through grid clamping action and is sufficiently negative to cut off the tube and to override the effects of the common grids, pins 2 and 7. The sync pulses applied to grid 9, however, are highly positive and drive the sync separator-amplifier out of cutoff and into saturation. Of course, the on–off action of the tube produces a negative train of sync pulses. But when noise spikes combine with the input video signal, they are coupled to both grids 2 and 9. Since control grid 2 has more control on plate current than screen grid 9, the negative noise spikes essentially override and cancel the effects of the positive noise spike at pin 9. The output signal at pin 8 thereby results in a noise-free sync train.

Transistorized Sync-Amplifier and Noise Cancellor

The figure below shows how a transistor connected in the emitter circuit of the sync separator-amplifier cancels noise. Since the base is returned to B+, the noise cancellor circuit Q2 normally conducts heavily. And since Q2 is saturated, it virtually acts like a shorted path for the emitter circuit of sync-separator Q1. When a noise spike cuts off the noise cancellor, the noise cancellor opens the path between Q1 emitter and ground, and thus cuts off the sync separator. By cutting off Q2 and thus Q1, the sync separator is unable to amplify the noise spike. Since the bias control reverse biases by clamping the diode D1 at the peak of sync tips, the normal signal does not find its way to transistor Q2. The diode will conduct, however, only when the negative noise spikes rise sufficiently high in value to forward bias the diode. At these instances, the negative noise spikes cause noise cancellor Q2 to act as a high resistance path in the emitter circuit of Q1. With an open emitter, the sync-clipper amplifier Q1 cuts off and does not amplify the noise spikes; thus, they are effectively cancelled.

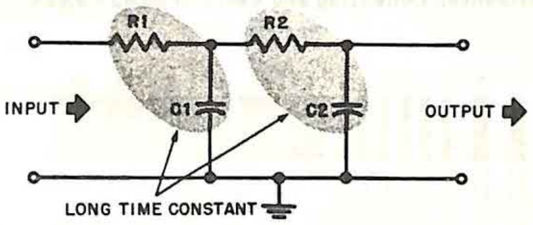
SYNC AMPLIFIER AND NOISE CANCELLOR



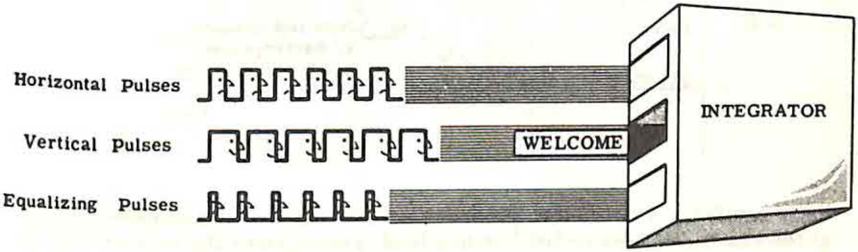
Separating the Pulses, The Integrating Circuit

When the sync pulses—horizontal, equalizing, and vertical—have been built up to a good level of strength, they are ready for *separation*. The sync pulse which arrives at the end of every scanned *horizontal* line must be fed to the *horizontal* oscillator to trigger it into action at the right moment, and the *vertical* pulse arriving at the end of each scanned field must be fed to the *vertical* oscillator. *Separating* these two types of sync pulses so that each will take its designated path is the job of special circuits. The vital circuit in sync separation—the circuit which actually works to separate the vertical from the horizontal pulses— is the *integrating circuit*.

The Integrating Circuit



Makes Use of the Vertical Pulses Only



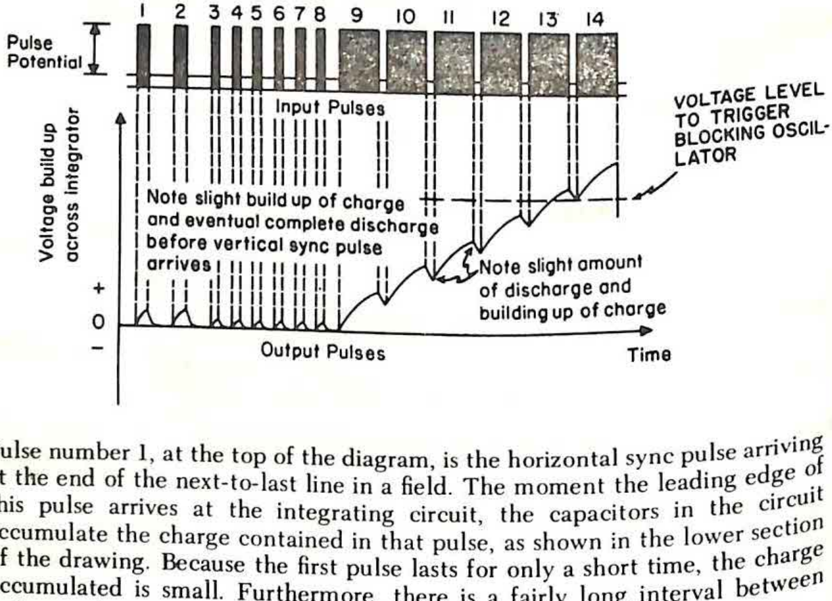
We can best begin our explanation of the integrator by saying that it is made up of resistors and capacitors, as shown. The output is taken off the last capacitor.

By definition, an integrator is a device which sums up instantaneous values. The output voltage is a function of the *duration* of the input voltage and also of its amplitude. In the television receiver the vertical integrator distinguishes between vertical and horizontal sync as well as equalizing pulses, and permits the vertical sync pulses to build up to a voltage level suitable for triggering the vertical sweep oscillator.

Integrating Action

Let us assume a series of sync pulses, all of the same height, but of different widths. First we have the horizontal sync pulses, (1-2) of short duration with substantial time in between. At the end of a field, the equalizing pulses 3-4-5-6-7-8 come along; these too are of short duration. After the first set of equalizing pulses comes the broad serrated vertical sync pulse. In the six serrated vertical sync pulses, we encounter a different shape—each of the serrations is a wide pulse, wider than either horizontal or equalizing pulses. Furthermore, the interval between pulses is so short, that the integrator capacitors do not have time to *discharge* too much before the next pulse comes along. Each vertical sync pulse provides additional charge.

How the Integrator Reacts to Horizontal, Equalizing and Vertical Sync Pulses

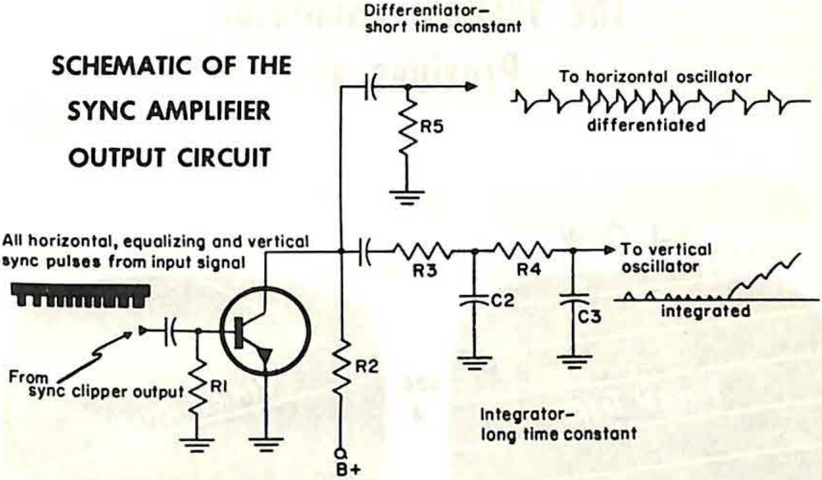

1
2
3
4
5
6
7
8
9
10
11
12
13
14
Pulse Potential
Input Pulses
VOLTAGE LEVEL TO TRIGGER BLOCKING OSCIL-LATOR
Voltage build up across integrator
Note slight build up of charge and eventual complete discharge before vertical sync pulse arrives
Note slight amount of discharge and building up of charge
+
0
−
Output Pulses
Time

Pulse number 1, at the top of the diagram, is the horizontal sync pulse arriving at the end of the next-to-last line in a field. The moment the leading edge of this pulse arrives at the integrating circuit, the capacitors in the circuit accumulate the charge contained in that pulse, as shown in the lower section of the drawing. Because the first pulse lasts for only a short time, the charge accumulated is small. Furthermore, there is a fairly long interval between pulse number 1 and pulse number 2.

By the time pulse 2 arrives, then, the charge in the integrating capacitors has leaked off. For pulse 2, a new charge is built-up, but it is dissipated before the next pulse in the procession comes along. For each of the thin horizontal and equalizing pulses, then, the charge built up by the integrator circuit is small and is fully dissipated before the first vertical sync pulse comes along.

Integrating Action (cont'd)

Now the serrated vertical sync pulses are applied to the integrator. These serrations are all wider than the horizontal or equalizing pulses, the charge each contains is greater, and the charge accumulated in the integrator circuit is greater. Pulse number 9 is the first of these pulses to reach the integrator circuit. It builds up a charge as shown. But the time interval between the trailing edge of 9 and the leading edge of 10 is so short, that before the charge built up by 9 has a chance to leak off very much, the arrival of pulse 10 *adds* to it. The effect of the whole train of serrations in the *vertical* sync pulse is to build up quite a high charge at the integrator output.



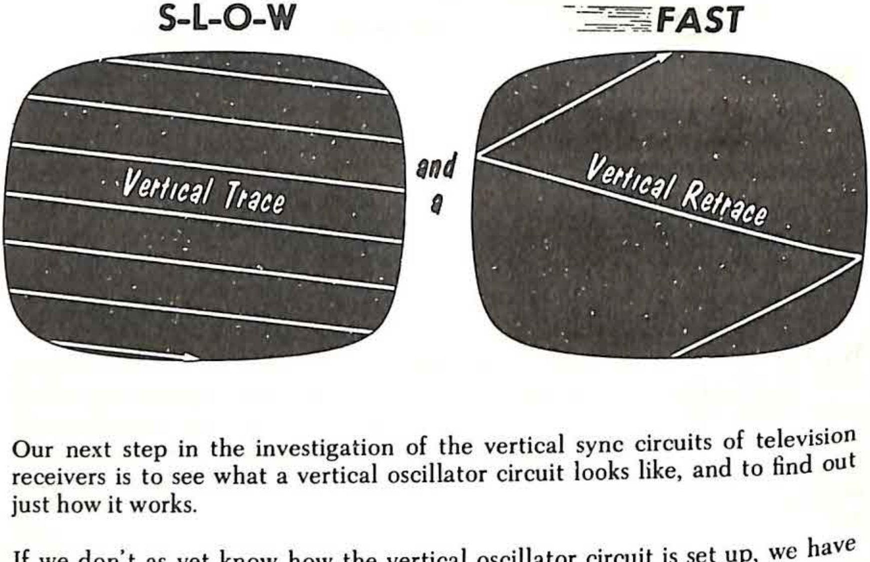
What we have just said indicates that the integrator builds *only* the serrated vertical sync pulse up to the triggering voltage. The horizontal and equalizing pulse charges have no effect. The very narrow equalizing pulses help dissipate any residual charge remaining from the horizontal pulses. This permits the buildup of voltage due to the six vertical sync pulses to be the *same* for each field time-wise, and so trigger the vertical oscillator at the same time for each field.

Across collector load resistor R2 appears a signal voltage made up of more or less squared, horizontal, equalizing, and vertical sync pulses. Part of this signal voltage is fed into the integrating circuit. The remainder of this same output signal voltage developed across R2 is fed into the horizontal sweep system which will be discussed later.

The Vertical Oscillator

Now we know that the integrator circuit builds the vertical sync pulse into an "effective force." But, why? There must be a reason behind this building up the vertical sync pulse. Remember what has been said about these sync pulses and the reason is clear. The vertical sync pulse *triggers* the vertical oscillator into pulling the scanning beam up and down over the face of the picture tube in *synchronism* with the camera scanning beam at the transmitting station. The swollen vertical pulse coming out of the integrator circuit, then, is to be applied to the vertical oscillator.

The Vertical Oscillator
Provides a



Our next step in the investigation of the vertical sync circuits of television receivers is to see what a vertical oscillator circuit looks like, and to find out just how it works.

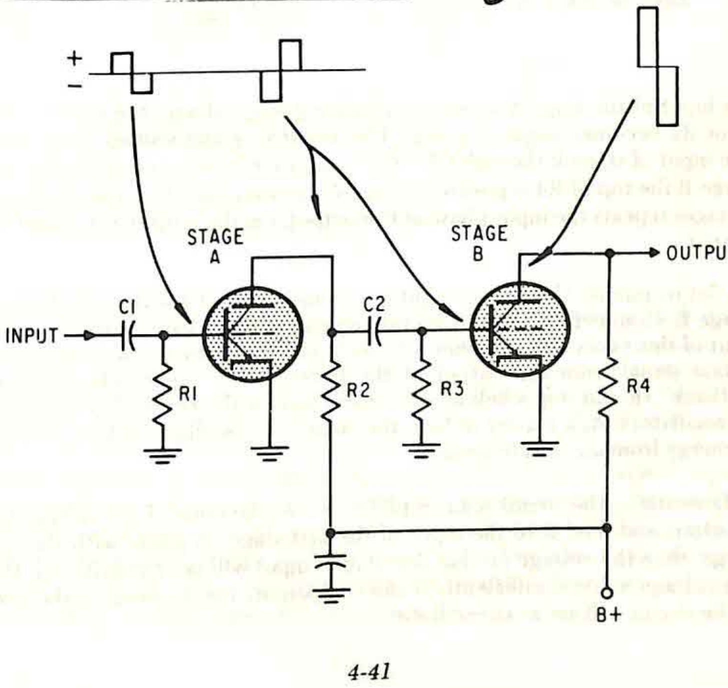
If we don't as yet know how the vertical oscillator circuit is set up, we have some idea how it works from Volume 2. The oscillator can be compared to an insect trying to climb up the slime-covered wall of a well. Trapped in this way, the insect is likely to be persistent. He journeys steadily upwards until, almost within reach of daylight, he slips dizzily back to where he started; he repeats the slow grind towards the top and once more slides swiftly back.

The Multivibrator

There are two general types of relaxation oscillators that are used in the vertical sweep system of television receivers. The first type, the multivibrator, is used in both vacuum-tube and transistorized televisions; the second type, the blocking oscillator, is used primarily in transistorized televisions. Although the multivibrator is a stranger to the person familiar only with radio receiver circuits, it is actually made up of resistance-capacitance (RC) amplifiers, a very common radio receiver circuit. As you will now see, two cascaded RC amplifiers, with only very minor modification, form a multivibrator.

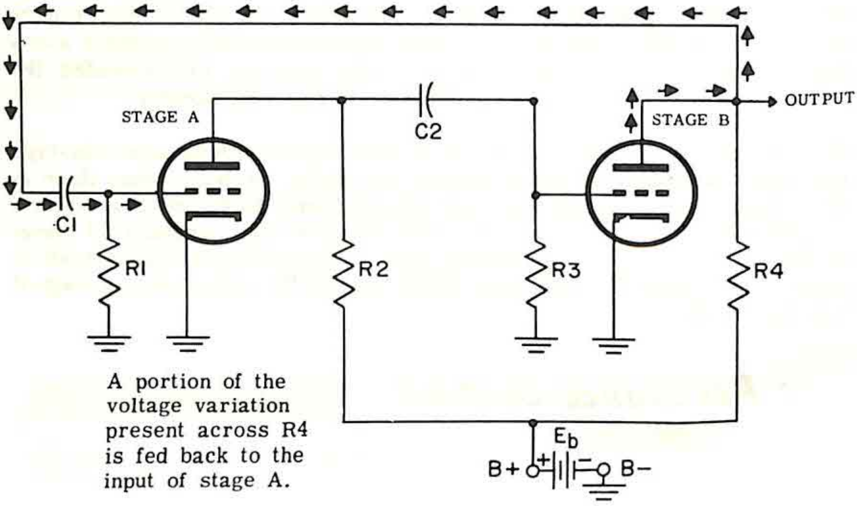
Since the circuit configurations and basic operation of both vacuum-tube-type and NPN transistor-type multivibrators are similar, we will discuss them as one. Thus, stages A and B, which are identical, may be regarded as either a vacuum-tube circuit or a transistor circuit. Stage A input capacitor C1 corresponds to stage B input capacitor C2; stage A bias resistor R1 corresponds to stage B bias resistor R3; and stage A load resistor R2 corresponds to stage B load resistor R4.

Two Resistance-Coupled Stages In Cascade



The Multivibrator (cont'd)

Feedback in the Multivibrator Circuit



A portion of the voltage variation present across R4 is fed back to the input of stage A.

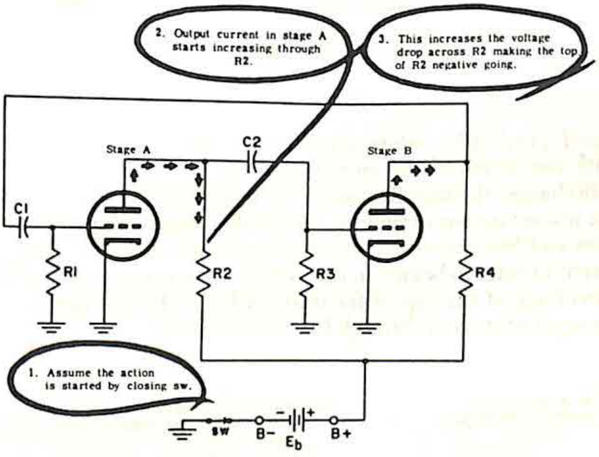
If the input of the stage A receives a positive-going voltage, the top of output resistor R2 becomes negative-going. This negative-going voltage is passed on to the input of stage B through C2. With a negative-going voltage on the input of stage B the top of R4 is positive-going. We can say then that the presence of two stages repeats the input phase at the output, i.e. the output is *in phase* with the input.

Now, let us modify the circuit slightly to couple part of the output of stage A to stage B. Connecting a wire from the top end of R4 to capacitor C1 links the output of this two-stage amplifier with its input; that is to say, we feed back an in-phase signal from the output of the system to its input. The expression "feedback" should ring a bell as it is a radio technical term used in connection with oscillators. As a matter of fact, the circuit can oscillate without receiving any energy from an outside source!

Fundamentally, the circuit is an amplifier. If we take some of the voltage from the output and feed it to the input of the first stage, *in phase* with the input voltage, then the voltage on that first stage's input will be *strengthened*. If the input voltage is raised sufficiently it can compensate for the *losses* in the circuit and the circuit will act as an oscillator.

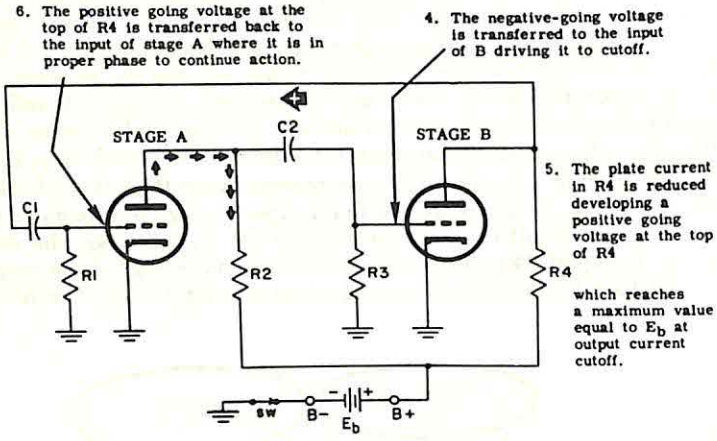
Electrical Action in the Multivibrator

When switch SW is closed, both stages conduct. Capacitors C1 and C2 charge to approximately the B+ voltage. The charging path for C1 is from ground, through R1 and R4, to B+ and for C2 from ground, through R3 and R2, to B+. It's impossible to find two tubes/transistors that are *exactly* the same. Even though the tubes/transistors and other components of stages A and B are theoretically identical, in practice they are not; one stage will conduct slightly more than the other. Assume that stage A conducts more heavily than stage B. Therefore, its output voltage will be decreasing faster than that of stage B. This negative-going voltage is applied to the input of stage B through coupling capacitor C2. As a result of phase inversion in the second stage, the voltage variation at the top of R4 is positive-going. This rise in voltage at the output of stage B is fed back to the input of the stage A, increasing its output current.

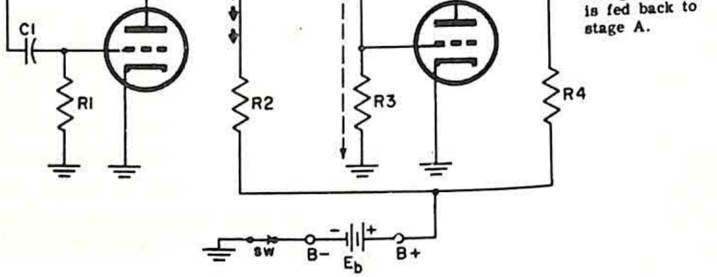

2. Output current in stage A starts increasing through R2.
3. This increases the voltage drop across R2 making the top of R2 negative going.
Stage A
C2
Stage B
C1
R1
R2
R3
R4
1. Assume the action is started by closing sw.
sw
B−
−
+
E_b
B+

If the output current in A is increased, the voltage at the top of R2 is driven even lower, the voltage at the top of R4 becomes more positive, and in turn the input of tube A is made still more positive. All of this action takes place much more rapidly than we can describe. The voltage of stage A's input rises very rapidly. At the same time, the voltage at the top of R2 is *dropping* at an equally rapid rate, and the input of tube B is speedily driven more and more negative. The rapid rise in voltage on input A and the fall in voltage on input B does not continue without reversal. After a short period, input B is driven to its cutoff point and even beyond it; output current in stage B ceases, and the voltage fed back to the input of A no longer rises. For a moment, then, the action of the circuit is at a standstill, with the input of A retaining its highly positive voltage, and the input of B being very negative.

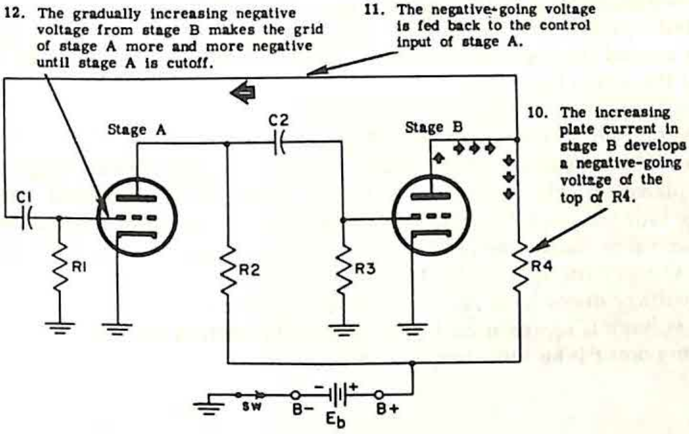
Electrical Action in the Multivibrator (cont'd)


6. The positive going voltage at the top of R4 is transferred back to the input of stage A where it is in proper phase to continue action.
4. The negative-going voltage is transferred to the input of B driving it to cutoff.
STAGE A
C2
STAGE B
5. The plate current in R4 is reduced developing a positive going voltage at the top of R4
which reaches a maximum value equal to E_b at output current cutoff.
CI
RI
R2
R3
R4
SW
B-
E_b
B+

As mentioned previously, while all this is going on C2 is accumulating a charge. With the action of the circuit temporarily stopped, C2 is able to discharge. It discharges through R3, but it can only do so slowly, since the resistor prevents an instantaneous discharge. As C2 discharges, the voltage of input B becomes less and less negative, until finally it is less negative than cutoff, and output current in stage B begins to rise. With the output current of B on the increase, the voltage at the top of R4 starts falling. This voltage decrease is fed back to the input of stage A through C1.

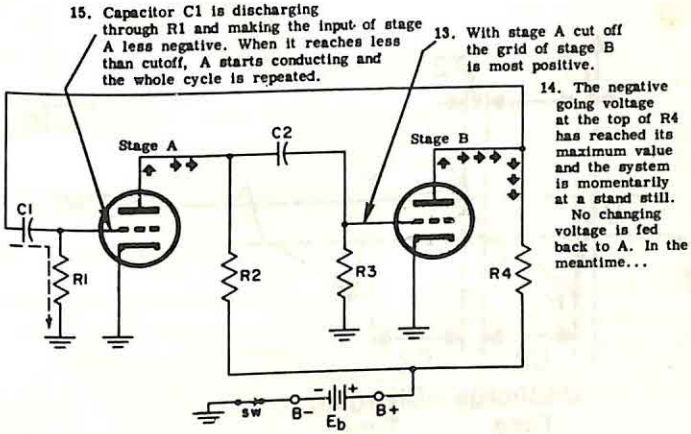

8. For a moment, circuit action stops.
9. Capacitor C2 discharges through R3 - eventually the input of stage B is less negative than cutoff, and current starts flowing in R4.
7. When stage B reaches output current cutoff no further changing voltage is fed back to stage A.
Tube A
C2
Tube B
CI
RI
R2
R3
R4
SW
B-
E_b
B+

Electrical Action in the Multivibrator (cont'd)


12. The gradually increasing negative voltage from stage B makes the grid of stage A more and more negative until stage A is cutoff.
11. The negative-going voltage is fed back to the control input of stage A.
10. The increasing plate current in stage B develops a negative-going voltage of the top of R4.
Stage A
C2
Stage B
C1
R1
R2
R3
R4
SW
B−
E_b
B+

The voltage on the input of A rapidly becomes increasingly negative, eventually going past the cutoff value. At cutoff the output current in A ceases altogether, and once more the system is at a standstill, with the input of A highly negative. During this quiet period, C1 discharges through resistor R1.

With the resistance of R1 opposing the flow of current, the capacitor discharge is achieved at a relatively slow rate, and the voltage on stage A slowly becomes less negative. Once more output current begins flowing in stage A, and a repetition of the whole cycle we have described takes place.

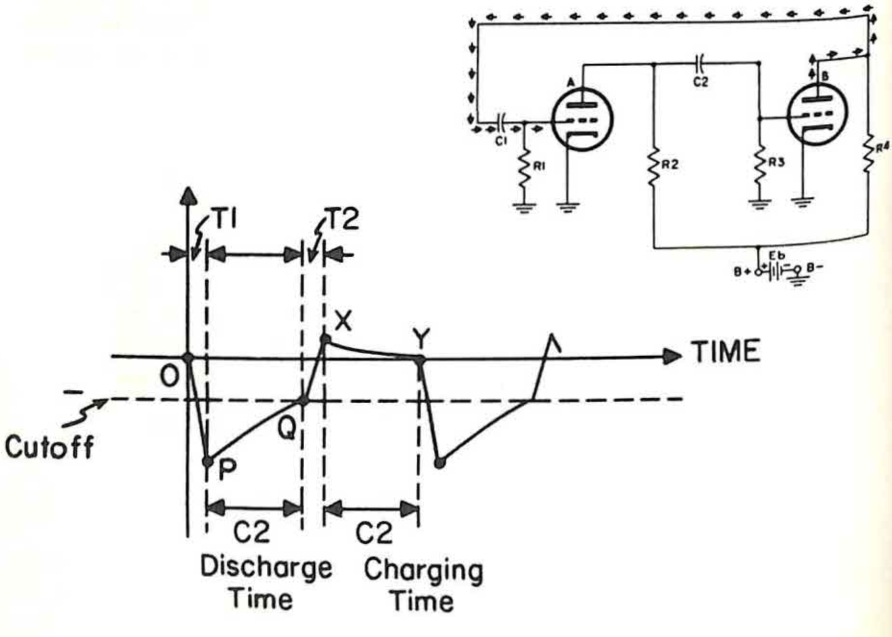

15. Capacitor C1 is discharging through R1 and making the input of stage A less negative. When it reaches less than cutoff, A starts conducting and the whole cycle is repeated.
13. With stage A cut off the grid of stage B is most positive.
14. The negative going voltage at the top of R4 has reached its maximum value and the system is momentarily at a stand still. No changing voltage is fed back to A. In the meantime...
Stage A
C2
Stage B
C1
R1
R2
R3
R4
SW
B−
E_b
B+

Wave Shapes in the Multivibrator

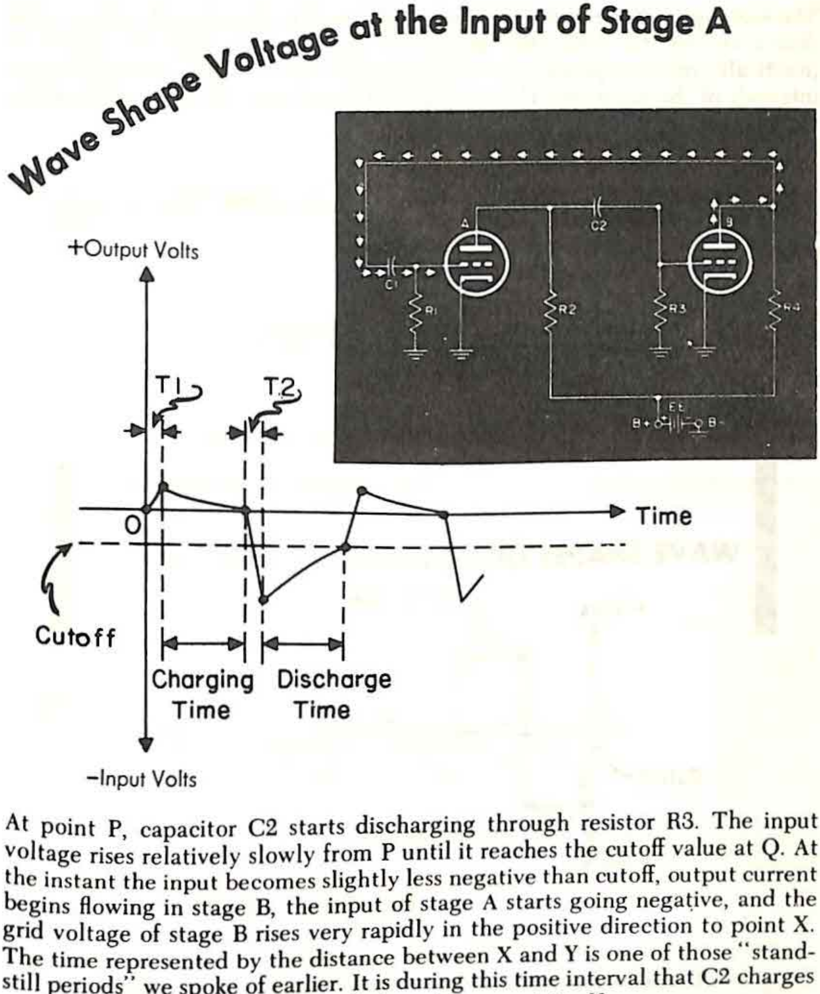
The word description of the multivibrator action that we have given is all very well, but a *picture* of what happens would be much better. Since our story revolves around the input of stage B for the most part, suppose we take a close look at the action there first.

The graph below shows us what is happening at the input of stage B in the multivibrator schemetic. At zero time—the time which marks the beginning of our explanation—the input voltage is zero. Then, as we explained, the input voltage falls very rapidly in the negative direction, with point P being the most negative value. Since time is measured horizontally the horizontal distance between O and P, designated by T_1, represents the *interval of time* in which the input voltage drops from zero to its most negative value. The output current cutoff voltage is represented by the horizontal dotted line. As shown in the diagram point P is far more negative than cutoff.

Wave Shape Voltage at the Input of Stage B



Wave Shapes in the Multivibrator (cont'd)



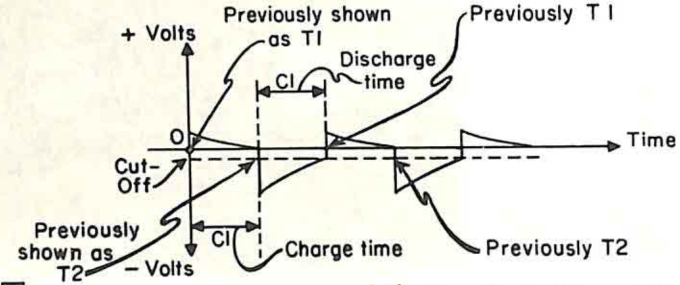
Wave Shape Voltage at the Input of Stage A

At point P, capacitor C2 starts discharging through resistor R3. The input voltage rises relatively slowly from P until it reaches the cutoff value at Q. At the instant the input becomes slightly less negative than cutoff, output current begins flowing in stage B, the input of stage A starts going negative, and the grid voltage of stage B rises very rapidly in the positive direction to point X. The time represented by the distance between X and Y is one of those "standstill periods" we spoke of earlier. It is during this time interval that C2 charges up again. After Y, of course, the whole action repeats itself.

If we wanted to show the waveform of the voltage on the input of stage A we could do so very easily remembering that, because of the phase-inversion action of a single stage, the input of stage A is in its positive phase while the input of B is in its negative phase. The input of stage B is in its negative phase from O to just an instant after Q. It is during this same time that input A is in its positive phase.

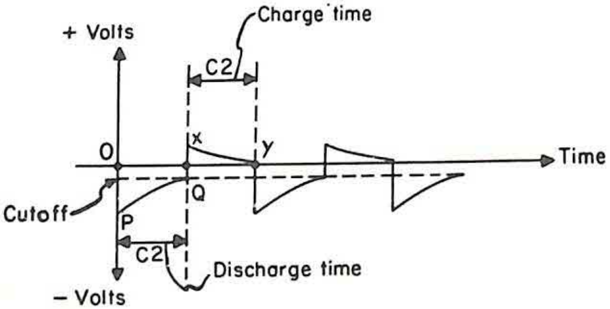
Frequency of the Multivibrator Wave

The waveforms illustrated have been exaggerated to show details. If they were drawn strictly to scale, the horizontal distances T1 and T2 would be practically zero compared, e.g., to the much longer charging and discharging intervals of the capacitors C1 and C2. The two waves, then, would look like this illustration.



(A) Input of Stage A

WAVE SHAPES OF VOLTAGES AT BOTH INPUTS



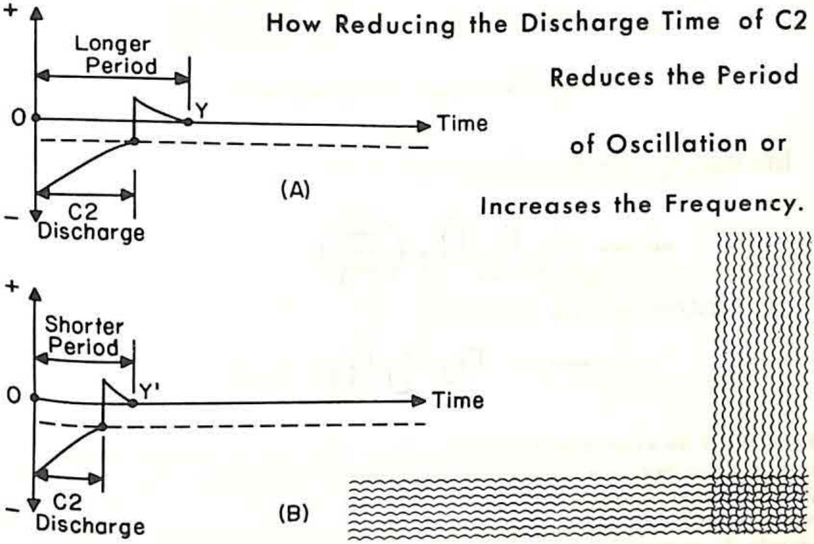
(B) Input of Stage B

Suppose we look for a moment at a drawing of stage B which shows that, at the start of the action of the multivibrator, the input voltage of stage B drops very sharply, then rises slowly as C2 discharges, and so on. At point Y the whole sequence of events begins over again, for Y marks the beginning of a second drop of the grid voltage followed by the slow discharge of C2. We can then say that the multivibrator has completed *one cycle* of oscillation when the input voltage goes through a variation from O to Y. The horizontal distance from *O* to Y is the time during which one cycle is completed, and this time interval is defined as the *period* of oscillation or frequency of the oscillator.

Frequency of the Multivibrator Wave (cont'd)

Is there any way we can *vary* the period of oscillation of the multivibrator? The time for the first half-cycle—the horizontal distance from O to Q—is occupied by the discharge of capacitor C2. Similarly, the time for the *second* half of the cycle, the distance from Q to Y is taken up by the charge of C2.

If we *reduce the time* C2 needs to charge or discharge, then the period of the oscillation will be shortened and the frequency will be raised. We do this by lowering the time constant of the circuit. C2 charges and discharges through R3. Hence, the resistance of R3 determines the length of time the capacitor takes to charge or discharge. By making R3 variable we can vary the period of oscillation of the multivibrator.



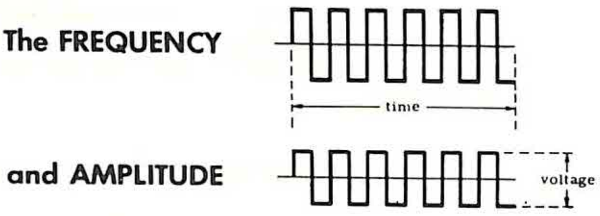
How Reducing the Discharge Time of C2 Reduces the Period of Oscillation or Increases the Frequency.

This illustration shows how the period of oscillation of the multivibrator can be changed by varying the amount of resistance through which C2 must discharge. In (A), the resistance is fairly large, and the capacitor takes a fairly long time to discharge; in (B) however, the size of the resistance has been reduced, and the time for the discharge of C2 has been similarly reduced. The period is shortened.

Shortening the period of the oscillator's electrical cycle has the effect of *increasing* the oscillator's *frequency*. If the time taken for a single cycle is *shortened, more cycles* can occur in *1 sec.*

Amplitude of the Multivibrator Wave

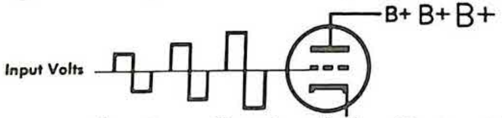
Although we have managed to change the frequency of the multivibrator oscillation, the *amplitude* of the two waves is still the same. This is not surprising; it is strictly in accord with the theory of oscillators. The amplitude and frequency of a wave are two different quantities, and it is entirely possible to change one without affecting the other. By another arrangement, we can change the *amplitude* of the multivibrator's wave.



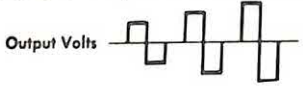
of the Multivibrator wave are independent.

-BUT-

Increasing the Amplitude of Output and Input Voltage



Increases the Amplitude of the Output Current

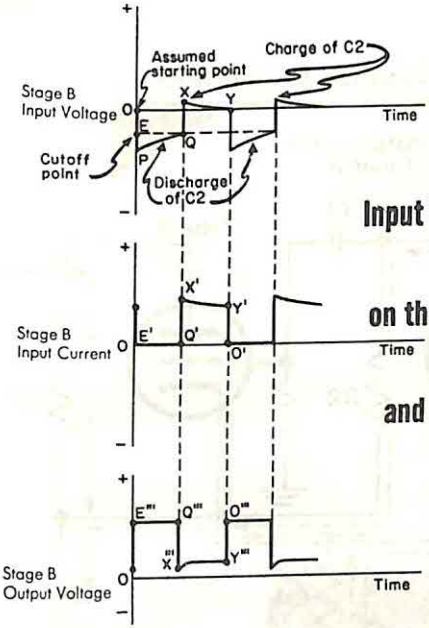


From what we know about the behavior of tubes and transistors, it should be easy to figure out a way to change the amplitude of the wave. The current that flows in either of the two multivibrator stages depends on the strength of the voltage that is furnished the plates/collectors of those stages by the power supply. If we increase the voltage of stage B, for example, the current flowing in the stage will be larger, and the voltage it feeds back to the input of stage A will also be greater. Obviously, then, the amplitude—or strength—of the multivibrator signal can be varied by changing the *plate/collector voltage* on one of the stages.

It is true, as we have just stated, that the output current of a stage depends on the voltage applied to the plate/collector by the power supply. But it is also true that this current of a stage depends on the varying signal applied to the stage's input. Given the voltage which appears on the input of stages A and B of the multivibrator, we can see what the output current form in either stage looks like. Suppose we examine stage B.

Output Current and Output Voltage Waveforms

The input voltage at stage B begins at zero, and drops to point P which is more negative than cutoff. Since the output current decreases as the input voltage becomes more negative, at point E of the input voltage waveform the output current is zero, since E marks cutoff voltage on the input. As long as the input voltage is at cutoff or is more negative than cutoff, the output current will remain at zero. Any negative voltage greater than E will have no effect on the zero output current.



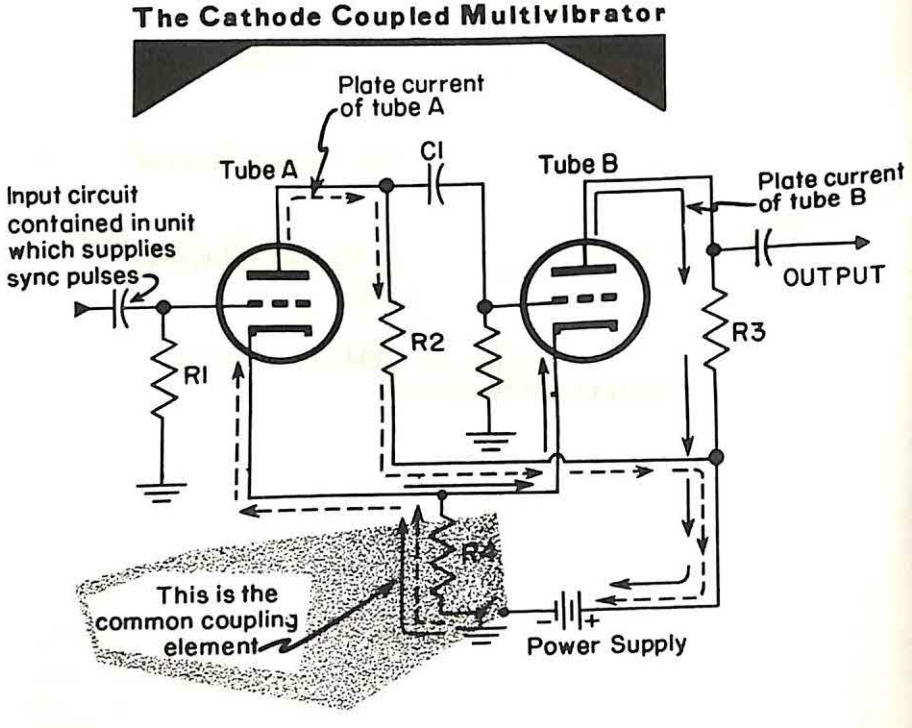
The Effect of the Input Voltage Variation on the Output Current and Output Voltage of Stage B

From P to Q, the input voltage rises slowly. But all during that time, the input is still more negative than cutoff. For the P′ to Q′ time interval, then, the output current remains at zero. But point Q is at the cutoff level. Any rise in input voltage above Q will produce a corresponding rise in plate current. From Q to X, where the input voltage rises very sharply, there will be an equally sharp rise in the output current (Q′ to X′). From X to Y the voltage falls off rather slowly, but never during that fall does it get as far negative as cutoff. The output current, therefore, varies accordingly.

If we construct the output current of stage A in the multivibrator in the same way, we will find that it is an inverted image of the stage current curve of stage B. Both these output current pictures are very nearly square waves. We shall see later just how important such square waves of output current are.

The Cathode-Coupled Multivibrator

Another type of multivibrator, made up in a slightly different way, is even more popular with television receiver manufacturers. This type of multivibrator, known as the *cathode-coupled* multivibrator, is a close cousin to the basic multivibrator. We retain the resistance coupling between the first and second stages, also the phase inversion of signal between the grid of the first tube and the grid of the second. But what seems to be missing in this circuit is the feedback arrangement by which the signal at the output of tube B is fed back to the grid of tube A.

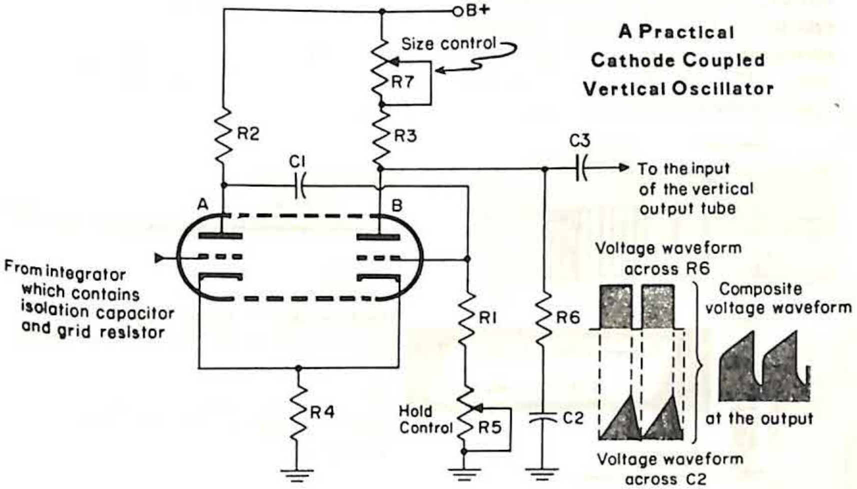

The Cathode Coupled Multivibrator
Plate current of tube A
CI
Tube A
Tube B
Plate current of tube B
Input circuit contained in unit which supplies sync pulses
OUTPUT
RI
R2
R3
R4
This is the common coupling element
− +
Power Supply

The feedback arrangement is in the circuit, but does not have the same form as in the basic multivibrator. Coupling between tube B and tube A occurs through resistor R4. Both cathodes have this resistor as a common plate current path. Plate current in tube B must pass through R4 on its way back to the cathode of tube B. Since this same resistor is in the cathode circuit of tube A, the signal developed across R4 as a result of the rise and fall of tube B plate current will be fed back to the grid of tube A.

The Practical Cathode-Coupled Multivibrator Circuit

The two triodes, tubes A and B, are within the single envelope of a duotriode. Note the capacitor C1, between the plate of tube A and the grid of tube B, and the cathode-coupling resistor, R4; both were in the previous circuit. But why two variable resistors, R5 and R7? What functions do R6 and C2 serve?

Although we have not seen these resistors before, it is easy to explain their purpose. R5 varies the total resistance between the grid of tube B and chassis, thereby determining the rate of discharge of C1—hence the frequency of the oscillator. Earlier we explained how varying the resistance between the grid of tube B and the chassis of the basic multivibrator has the effect of changing the *frequency* of the oscillator. We can go still further. You might recall from an early lesson that the "hold" control in the vertical oscillator is the device by means of which the frequency of the vertical oscillator is regulated—R5 is the *vertical hold control.*



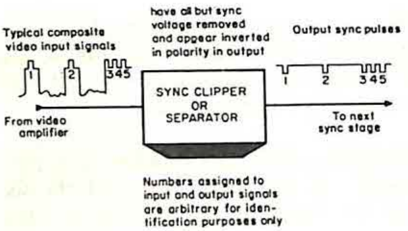
A Practical Cathode Coupled Vertical Oscillator

B+
Size control
R7
R2
R3
C3
CI
A
B
To the input of the vertical output tube
Voltage waveform across R6
From integrator which contains isolation capacitor and grid resistor
Composite voltage waveform
RI
R6
R4
Hold Control
R5
C2
at the output
Voltage waveform across C2

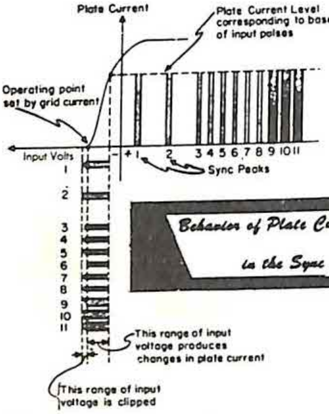
Varying the resistance of R7 controls the total resistance between the plate of tube B and the positive terminal of the B supply. If this resistance is *increased,* the voltage at the plate of tube B decreases. A variation of the plate voltage on tube B results in a change in the *amplitude* of the multivibrator output. R7 is the *vertical size control.*

As the diagram shows, the grid of tube A is connected to the vertical integrator circuit. The idea behind this connection is that the large vertical sync pulse developed by the integrator may keep the oscillations of the multivibrator under control. Notice also that a resistor and capacitor in series—R6 and C2—are wired from the plate of tube B to chassis.

The function of the Sync Clipper


Typical composite video input signals
have all but sync voltage removed and appear inverted in polarity in output
Output sync pulses
1
2
345
SYNC CLIPPER OR SEPARATOR
From video amplifier
To next sync stage
Numbers assigned to input and output signals are arbitrary for identification purposes only

2. *The Sync Amplifier and Noise Cancellor.* In this highly effective circuit, transistor Q2 completes the emitter path of Q1 during noise-free conditions. When noise spikes arrive, Q2 cancels the noise by opening the emitter path to Q1.

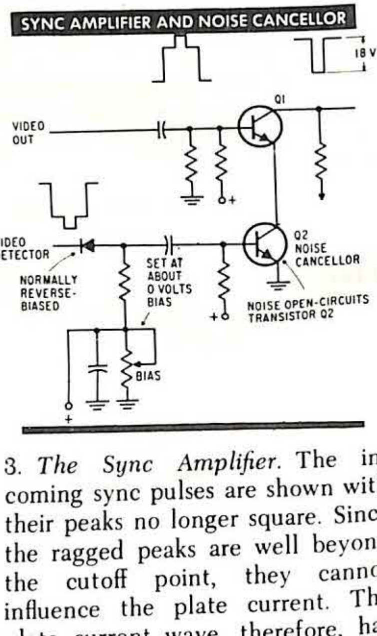


Behavior of Plate Current in the Sync Amplifier

4. *The Integrating Circuit* consists essentially of series-resistance and shunt-capacitance, the output being taken off the last capacitor. The output voltage is a function of the duration and amplitude of the input voltage. The vertical integrator distinguishes between vertical and horizontal sync as well as equalizing pulses.

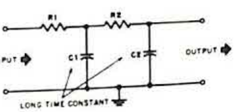
1. *The Sync Clipper or Separator* removes the sync pulses from the complete video signal, and discards the remainder of the signal. The output signal is made up of the same sync pulses that were sitting on top of the pedestals of the input signal, but the pulses appearing in the output signal are inverted.

SYNC AMPLIFIER AND NOISE CANCELLOR

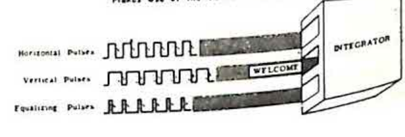


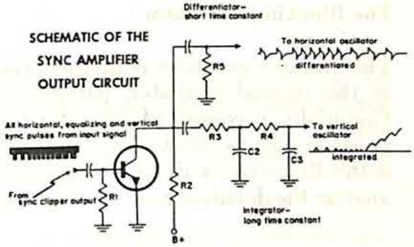
3. *The Sync Amplifier.* The incoming sync pulses are shown with their peaks no longer square. Since the ragged peaks are well beyond the cutoff point, they cannot influence the plate current. The plate current wave, therefore, has sharp corners.

The Integrating Circuit



Makes Use of the Vertical Pulses Only

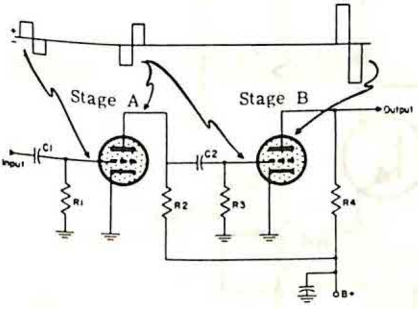



SCHEMATIC OF THE SYNC AMPLIFIER OUTPUT CIRCUIT

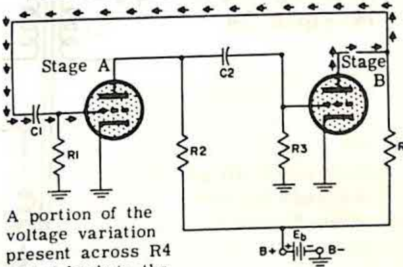
5. *Integrating Action.* The serrated vertical sync pulses are applied to the integrator. These serrations are all wider than the horizontal or equalizing pulses. The charge accumulated in the integrator circuit increases with each serration. The integrator builds only the serrated vertical sync pulse up to the triggering voltage.

The horizontal and equalizing pulse charges have no effect. The very narrow equalizing pulses help dissipate any residual charge remaining from the horizontal pulses. The buildup of voltage due to the six vertical sync pulses is the same for each field time-wise, and so triggers the vertical oscillator at the same time for each field. Across the plate load resistor R2 appears a signal voltage made up of more or less squared, horizontal, equalizing, and vertical sync pulses. Part of this signal voltage is fed into the integrating circuit. The remainder of this same output signal voltage developed across R2 is fed into the horizontal sweep system.

Two Resistance-Coupled Stages In Cascade



Feedback in the Multivibrator Circuit



A portion of the voltage variation present across R4 is fed back to the input of stage A.

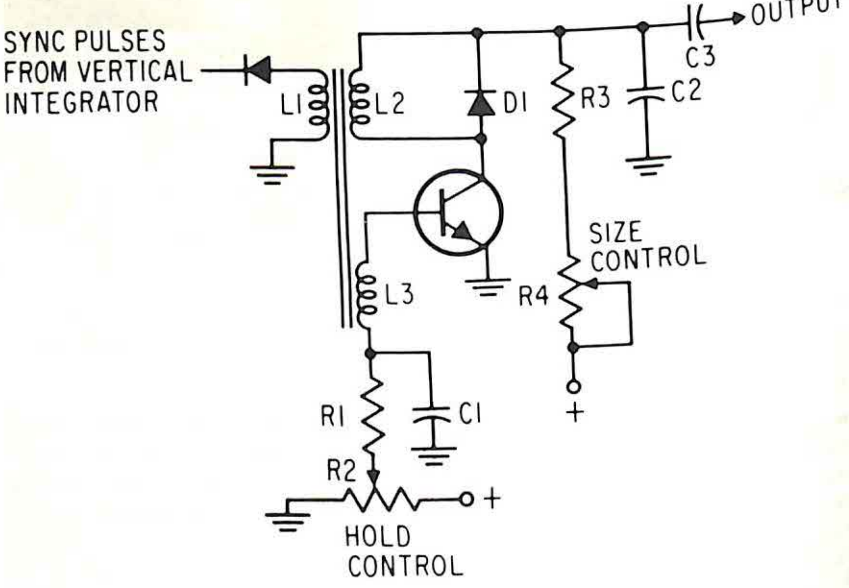
6. *The Multivibrator.* Consider the two-stage resistance-capacitance coupled amplifier. If the input of stage A receives a positive-going voltage, the top of output resistor R2 becomes negative-going and this voltage is passed to the input of stage B and the top of R4 is positive going. We can say that the output is in phase with the input. Let us now connect the lead labeled output to the input. We feed back an in-phase signal from the output of the system to its input. If the input voltage of the first tube is raised sufficiently, the circuit losses are compensated. The circuit will act as an oscillator.

The Blocking Oscillator

The blocking oscillator is another type of relaxation oscillator frequently used as the vertical oscillator, particularly in transistorized television receivers. Essentially, it consists of a transformer that develops a high-amplitude narrow pulse, and an RC network in the base circuit that has a slow discharge time. It is this RC network that determines the frequency of the oscillator. Now let's analyze the details of how the blocking oscillator works.

First assume that a small positive bias voltage is applied to the NPN transistor base. Thus, the forward biased emitter-base junction causes current to flow from the emitter to the collector and through L2, R3, and part of R4 to B+. Since diode D1 is reverse biased (its anode faces against the flow of current), the diode acts like an open circuit.

Because of the voltage drops across resistors R3 and R4, the voltage at the top of R3 swings downward (negative-going). With L2 and L3 wound on the same iron core, the transformer acts to couple and reverse the phase of the voltages from L2 to L3. Thus, when the collector swings negatively, the voltage coupled back to the base is positive which further helps the transistor to conduct.



The Blocking Oscillator (cont'd)

This positive feedback further increases the collector current, causing the collector voltage to swing downward even more. The phase-reversed feedback voltage increases the positive potential on the base, and collector current continues to rise rapidly. But collector current cannot rise indefinitely because saturation soon occurs.

Since the feedback voltage to the base depends on changes in collector current, the failure of the collector current to rise any further means that the transfer of positive voltage to the base ceases. Without the feedback to sustain it, the collector current starts to fall. With falling collector current, the voltage drop across the resistor in the collector circuit is reduced and the collector voltage becomes positive-going. The voltage fed back to the base is now negative. With negative voltages applied to the base, collector current in the transistor drops rapidly, making the collector even more positive. Eventually the base is driven so far negative that the transistor is cut off.

With the base more negative than cutoff, collector current ceases completely. Now we have an "inactive" period as in the multivibrator. During this inactive period C1 discharges, raising the base voltage slowly in the positive direction. When it is slightly above cutoff, current flows once again.

The blocking oscillator just described is free running. Vertical sync pulses, coupled to the transistor base through L1, will synchronize the circuit.

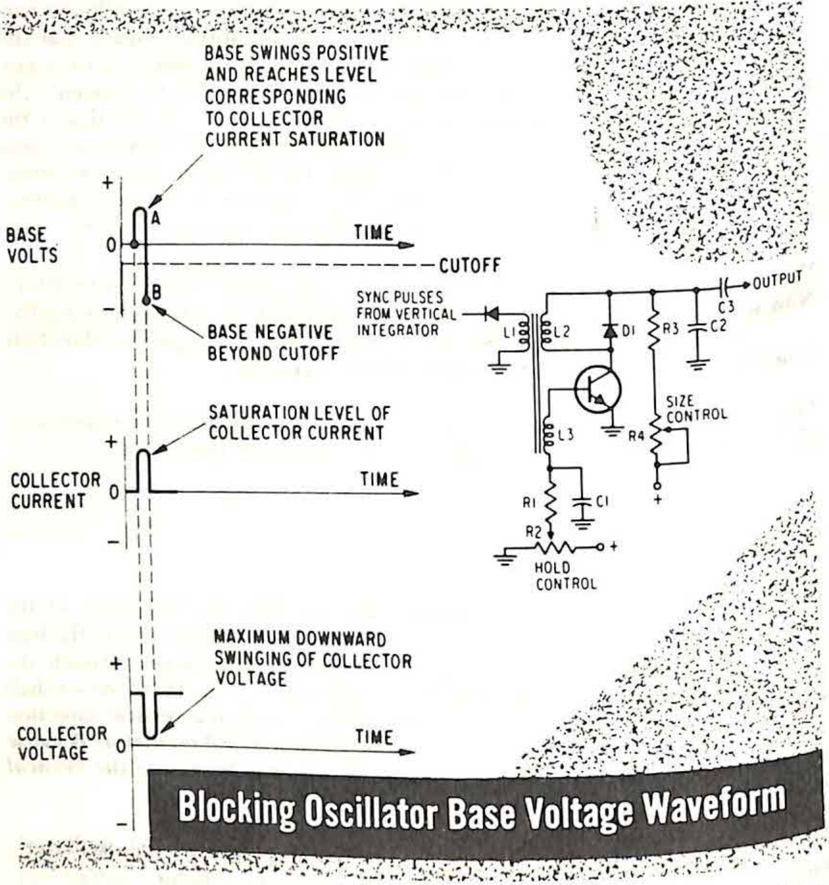
Controls in the Blocking Oscillator

Just as we did with the multivibrator, we can vary the *frequency* of the blocking oscillator by varying the time of discharge of the capacitor in the base circuit. Since that capacitor—C1 in the schematic—discharges through the base resistors, we can vary the time of the discharge by varying R2. As we shall find, any tendency of the picture on the screen to roll in a vertical direction can be corrected by adjusting the frequency of the vertical oscillator. Because proper setting of R2 can hold the picture steady, it is known as the *vertical hold control.*

Changing the resistance of R4 can change the *amplitude* of the oscillator's output waveform. Since the amplitude of the vertical oscillator's output controls the height of the picture, R4 is called the *vertical size control.* In most receivers, the vertical size control is on the back of the chassis for the service technician's use. The *hold* control is usually placed on the front panel for the set-owner's convenience if the picture should slip either up or down.

Waveforms in the Blocking Oscillator

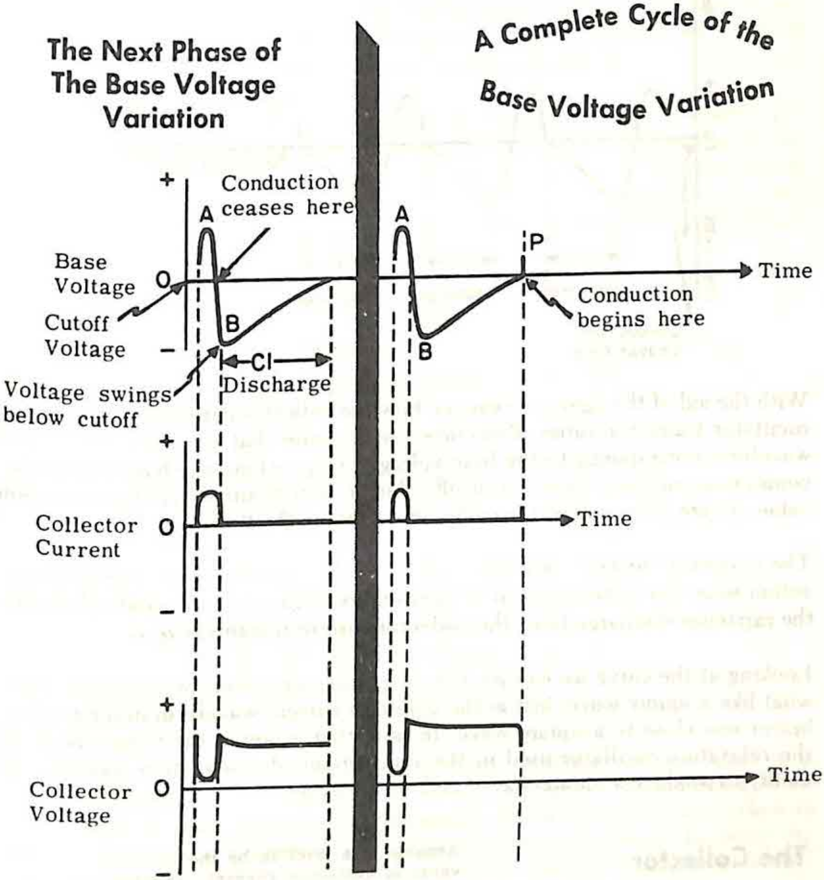
From the description we have just given, we should be able to construct the waveform of the blocking oscillator base voltage. The whole cycle of action begins with the base voltage going slightly positive from a zero value. Both collector current and base voltage rise rapidly together. Then, when saturation is reached, the base voltage drops just as rapidly until it becomes even more negative than cutoff. Just this part of the cycle is illustrated.


BASE SWINGS POSITIVE AND REACHES LEVEL CORRESPONDING TO COLLECTOR CURRENT SATURATION
+
A
BASE VOLTS
0
TIME
CUTOFF
B
−
BASE NEGATIVE BEYOND CUTOFF
SYNC PULSES FROM VERTICAL INTEGRATOR
L1
L2
D1
R3
C2
C3
OUTPUT
SIZE CONTROL
R4
L3
SATURATION LEVEL OF COLLECTOR CURRENT
+
COLLECTOR CURRENT
0
TIME
−
R1
C1
R2
+
HOLD CONTROL
MAXIMUM DOWNWARD SWINGING OF COLLECTOR VOLTAGE
+
COLLECTOR VOLTAGE
0
TIME
−

Blocking Oscillator Base Voltage Waveform

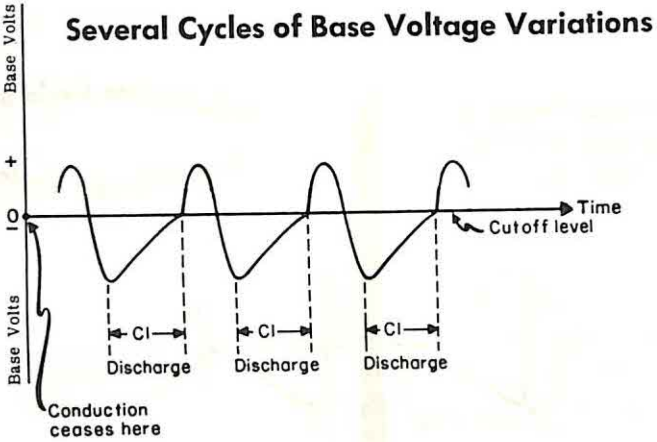
The base voltage is shown rising very quickly to a maximum at A, then dropping just as sharply to point B, which is far more negative than cutoff. B, now, is just the beginning of the quiet period during which the capacitor C1 discharges. At point B, the field around L2 collapses and tries to swing the voltage positively. When this tries to happen, diode D1 conducts, acts like a short, and quickly dampens any possible voltage swing.

Waveforms in the Blocking Oscillator (cont'd)



The next phase is the quiet period, with the base voltage rising slowly, along with the capacitor discharge, until cutoff is reached. Once the cutoff point is reached, the very rapid rise in base voltage takes place again, and the cycle is complete at point P. Of course, the base voltage does not stop at P; it keeps rising until it hits a peak at the same level as point A, and goes through exactly the same motions as it did before.

Waveforms in the Blocking Oscillator (cont'd)

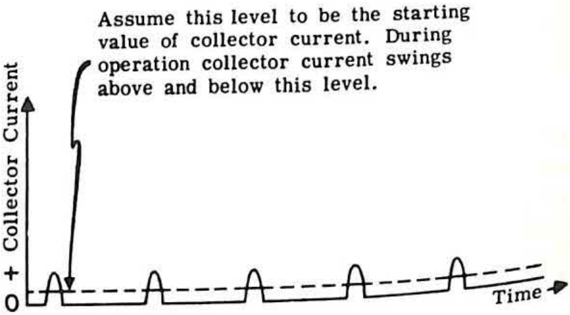

Several Cycles of Base Voltage Variations

With the aid of the figure, we can see how the collector current in the blocking oscillator transistor varies. Remembering the rule that the collector current waveform corresponds to the base voltage *except* where the base voltage becomes *more negative* than the cutoff value or more positive than the saturation value, we are able to draw the collector current in the transistor.

The collector current curve does not show the complete capacitor discharge action since that takes place at voltages more negative than cutoff. All during the capacitor discharge time, the collector current remains at zero.

Looking at the curve we can see that this collector current waveform is somewhat like a *square wave*, just as the collector current waveform in the multivibrator was close to a square wave. In fact, that is one of the requirements of the relaxation oscillator used in the sync circuit of a television receiver—its ability to produce a square-waved collector current.

The Collector Current in the Blocking Oscillator

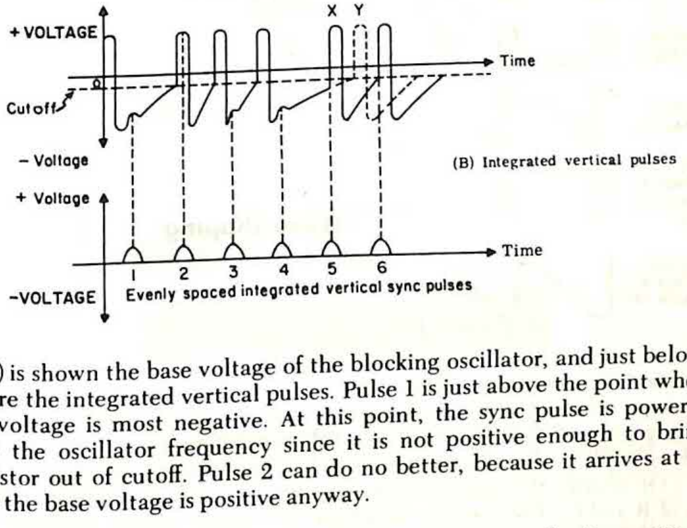

Assume this level to be the starting value of collector current. During operation collector current swings above and below this level.

Syncing the Vertical Blocking Oscillator

We have seen how the integrator circuit adds the vertical sync pulse serrations into one pulse while ignoring the other sync peaks. The vertical sync pulse at the integrator output is fed to the blocking oscillator to force it to operate at the vertical frequency—that is, 60 Hz. The vertical oscillator is designed to run free at *approximately* that rate. Applying the integrated vertical sync pulse to the base of the vertical oscillator "drives" it at this frequency.

Remember that the output of the integrator consists of pulses of *positive* polarity. *Positive* pulses, when applied to the base of the blocking oscillator, can raise the base above its cutoff value, and so force it to start conducting sooner than it normally would. By applying pulses of the correct frequency we can force the oscillator to conduct at the precise instant necessary for correct functioning frequency-wise (synchronization).

How the Vertical Integrated Pulse Forces the Vertical Oscillator into Synchronization

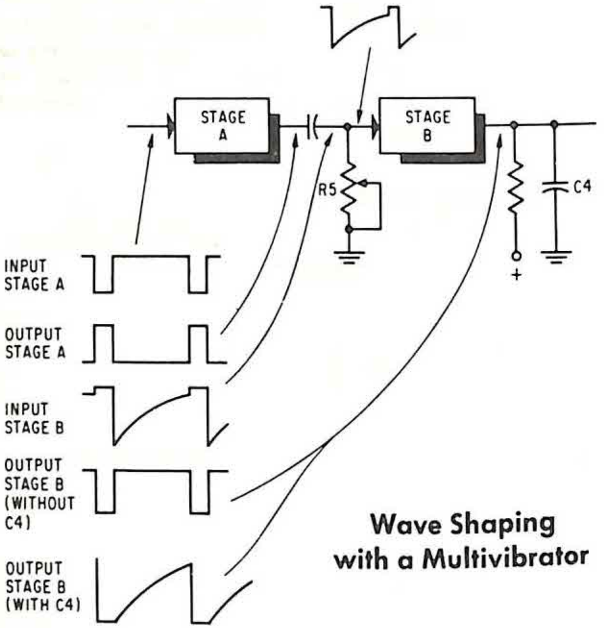

(A) Oscillator base voltage varies slightly in frequency until triggered
X
Y
+ VOLTAGE
Time
0
Cutoff
– Voltage
(B) Integrated vertical pulses
+ Voltage
Time
1
2
3
4
5
6
–VOLTAGE
Evenly spaced integrated vertical sync pulses

In (A) is shown the base voltage of the blocking oscillator, and just below it, in (B), are the integrated vertical pulses. Pulse 1 is just above the point where the base voltage is most negative. At this point, the sync pulse is powerless to affect the oscillator frequency since it is not positive enough to bring the transistor out of cutoff. Pulse 2 can do no better, because it arrives at a time when the base voltage is positive anyway.

Pulses 3 and 4 are in the same category as pulse 1. But pulse 5 appears on the scene when the base voltage of the oscillator is approaching the point where the transistor is ready to "fire." Pulse 5 adds just enough positive voltage to trigger the blocking oscillator into conduction at X. The broken line illustrates what the timing (Y) of the oscillator *would have been* had the triggering pulse not come along. From this moment on, the integrator pulses keep the blocking oscillator synchronized.

Sawtooth Shaping

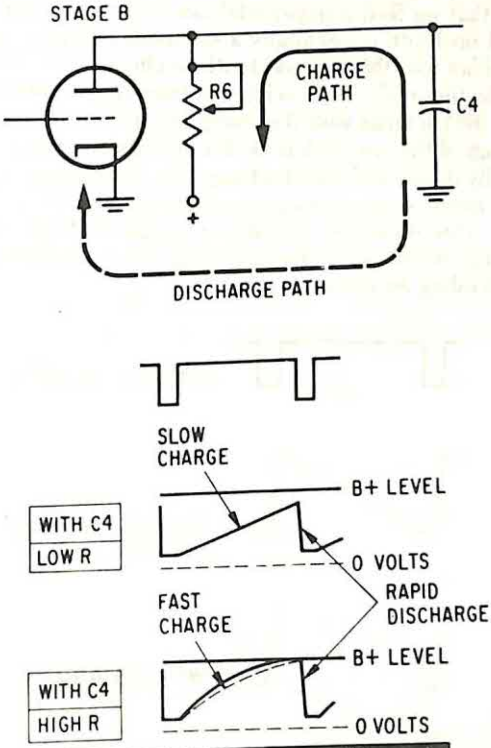
Earlier you learned how multivibrators generated a series of square waves. By adjusting the input resistance (R5) to stage B, you saw that you can change the duration of stage B cutoff, and thus, change the duration of the square wave from the output of stage B. This series of square waves must now be changed to a series of sawtooth waveforms which we will need to drive the vertical output sweep circuits.



Wave Shaping with a Multivibrator

To generate the sawtooth at the multivibrator output, we simply connect C4 to the output of stage B. Thus, when stage 2 conducts and operates like a short between plate and cathode, capacitor C4 completely discharges. As soon as stage B cuts off, we find that capacitor C4 begins charging through resistor R to B+. Of course, the capacitor charges at a rate which depends upon the values of R and C. Thus, when you adjust the variable resistor to a high value resistance, the capacitor will charge at a much slower rate. And as it charges, the voltage gradually rises toward the B+ level. Since capacitor C4 charges slowly, it does not store much positive voltage before the tube conducts again. At that time, the capacitor quickly discharges through the low resistance path of the tube, causing the capacitor voltage to fall sharply almost to zero volts. Thus, you see the results of a slow charge path providing a slow rise time, and a fast discharge path providing a fast fall time.

Sawtooth Shaping (cont'd)



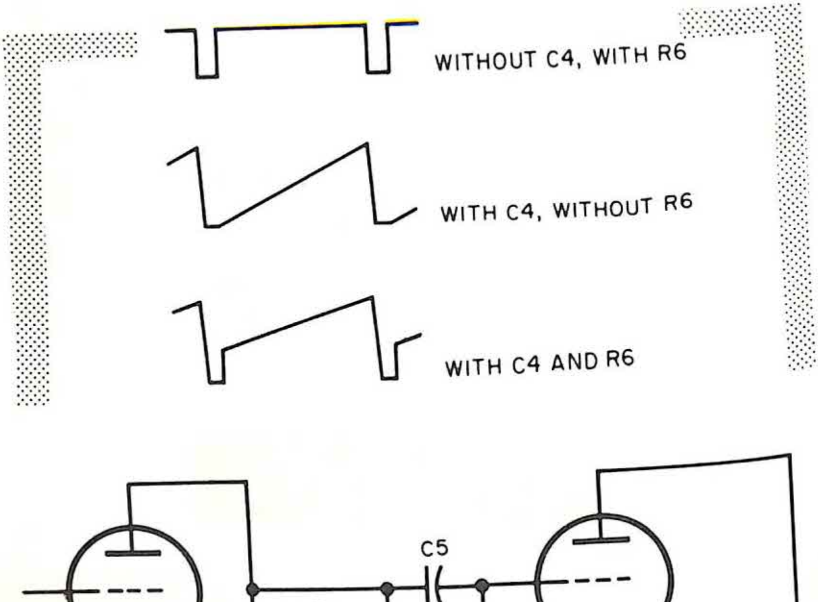
Values of R and C Affect Shape of Sawtooth Wave

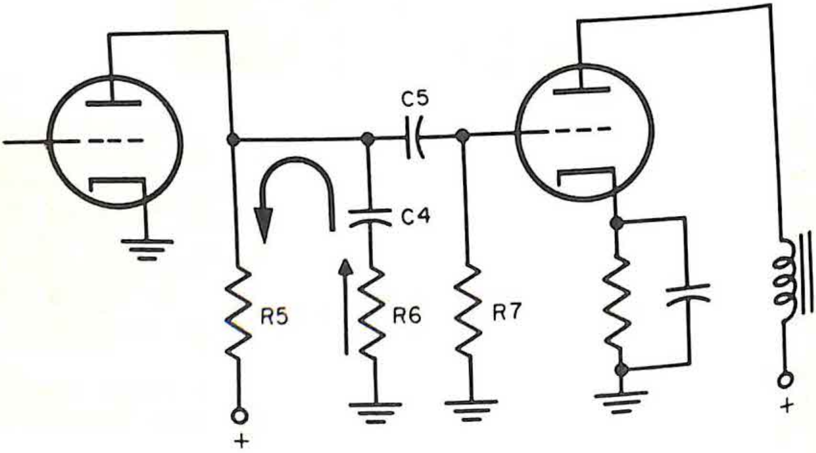
Now look what happens when we adjust the potentiometer for a low resistance value. When stage B cuts off for the long duration, the capacitor charges rapidly through the high resistance. So rapidly, in fact, that the capacitor charge reaches the B+ level and flattens to the steady B+ voltage level. Notice, too, that before the sawtooth flattens, there is a serious curvature. This curvature is called *nonlinearity*. This nonlinearity is further compounded by the sawtooth "topping-off" and becoming flat. Once it "tops-off", the sawtooth remains flat until stage B conducts and discharges the capacitor.

Shortly, you will see that this variable resistor is called either a vertical linearity or vertical size (height) control depending upon which characteristic of the sawtooth it affects most.

Sawtooth Shaping (cont'd)

Later in this lesson, when we discuss the details of vertical output amplifiers, you will notice that we feed a trapezoidal sawtooth to the vertical amplifier. The trapezoidal sawtooth is essentially a sawtooth riding on top of a square wave. The amplifier uses this type sawtooth to effectively and efficiently feed the vertical deflection coils. To develop this trapezoidal sawtooth, we simply insert a resistor (R6) in series with the charging capacitor (C4). As you already know, the bottom of the sawtooth is flat for only a short period when the trigger pulse virtually shorts, and thus discharges C4. By inserting R6 in the charge path of C4, the initial surge of charging current through R6 to C4 sees the resistance of R6. This resistance provides a sudden voltage drop, while the reactance of C4 is almost zero. The sum of the two voltage drops combine to form a sawtooth riding on a square wave.

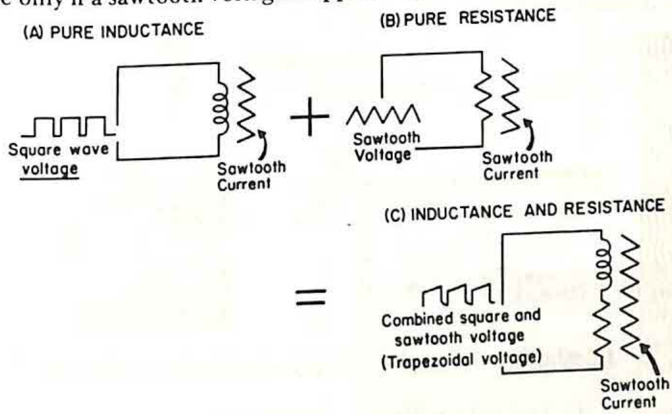




Feeding the Vertical Deflection Coils

Why should we want a summed-up voltage having this so-called *trapezoidal* waveform? The reason is that television receivers use electromagnetic deflection to sweep the electron beam up and down the face of the picture tube. This deflection is produced by the vertical deflection coils which are large, specially shaped inductors. To obtain the linear sweep so necessary for an undistorted picture, the *current* (not voltage!) through the inductors must have a sawtooth waveform. Now the question is: "What kind of voltage is required to cause a sawtooth current to flow through an inductor?"

It is well known that voltage having a square-wave form will cause a sawtooth current to flow through a *pure* inductance having no resistance. But practical deflection coils *do* have resistance. As we know from dc theory, the current through a resistor always has the same form or shape as the applied voltage. Thus, we can conclude that a sawtooth current will flow through a pure resistance only if a sawtooth voltage is applied across it.

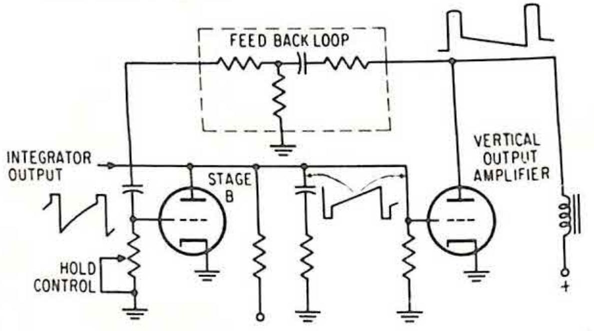


Let us now combine these two ideas in the manner suggested by the above figure. A trapezoidal voltage—comprising a combined square-wave and sawtooth voltage—applied across the terminals of a practical deflection coil having both inductance and resistance, should result in a sawtooth current through the combination. The fact that it does is borne out in practice. Remember a trapezoidal voltage produces a sawtooth deflection current in a practical vertical deflection coil. The trapezoidal waveform is then RC coupled to the vertical output amplifier. Here the amplifier input operates as a conventional amplifier and develops signal bias in the grid circuit. At the grid, the sawtooth voltage gradually rises and thus gradually raises the plate current in the tube. The resulting output voltage is a negative-going sawtooth waveform. Since this negative-going sawtooth has voltage characteristics similar to those at the output of stage 2 of the multivibrator, manufacturers combined the vertical oscillator with the amplifier.

Combining the Vertical Oscillator and Vertical Output

Look back for a moment at the output of stage B of the multivibrator. Notice that the asymmetrical square wave has long duration negative pulses similar to those developed in the vertical output stage. Now if we eliminate stage A of the multivibrator and couple the vertical output through the feedback loop to the input of stage B, as shown here, we have all the advantages of the multivibrator and amplifier stages. Since the amplifier develops a high voltage pulse, the feedback loop must be designed to attenuate and reshape the pulse so it effectively drives the oscillator stage.

Notice that the feedback loop returns the negative vertical output pulses to the oscillator stage. There, the RC network develops a negative voltage that cuts off the oscillator for a duration that is varied by the vertical hold control. Varying this hold control will, of course, vary the RC discharge time of the oscillator grid circuit. Furthermore, notice that the basic RC compoments used in the vertical oscillator are similar to those used in stage B of the multivibrator that we discussed earlier.



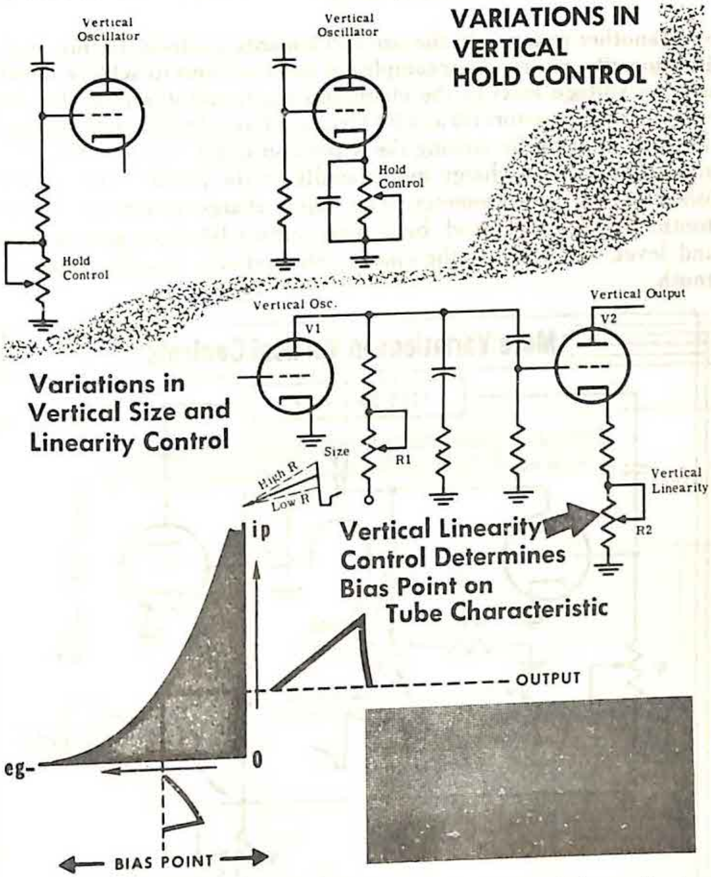
Combining Vertical Oscillator and Vertical Output

Variations in the Vertical Oscillator—Output Stages

Let's examine some of the significant circuit variations of the vertical oscillator-output stage, such as the vertical hold, linearity and size controls. The vertical hold control, along with its associated capacitor forming the RC time constant circuit, is used in either the grid or cathode circuit of vacuum tubes, or it is used in the base or emitter circuit of transistors. The purpose of the variable RC network is to vary the value of voltage that holds the tube or transistor cutoff.

A typical location for the size control is in the plate circuit of the oscillator, as shown by R1 below. Here the circuit is designed so that R1 will vary primarily the amplitude of the sawtooth. Linearity control R2 is often found in the cathode of the vertical output and, of course, helps to straighten the sawtooth rise time.

Variations in the Vertical Oscillator—Output Stages (cont'd)

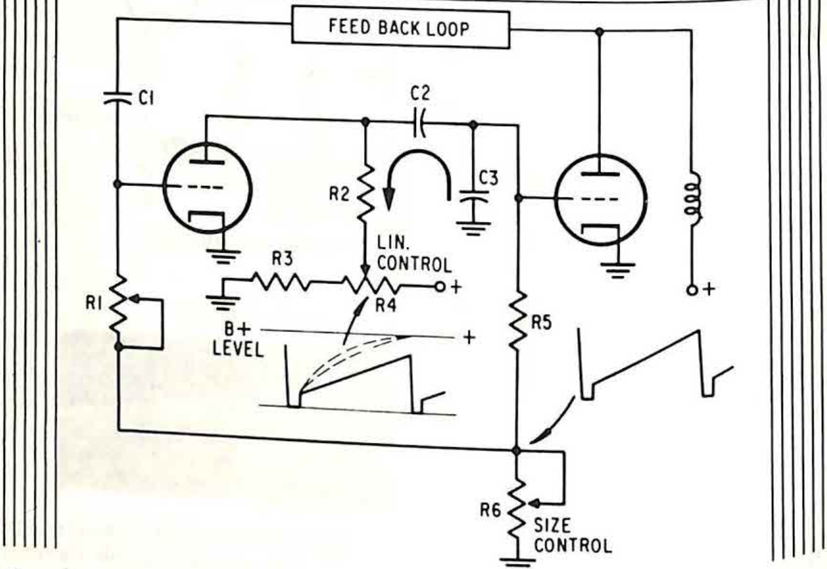

Vertical Oscillator
Hold Control
Vertical Oscillator
Hold Control
VARIATIONS IN VERTICAL HOLD CONTROL
Vertical Osc.
V1
Vertical Output
V2
Variations in Vertical Size and Linearity Control
Size
R1
High R
Low R
Vertical Linearity
R2
ip
Vertical Linearity Control Determines Bias Point on Tube Characteristic
OUTPUT
eg-
0
BIAS POINT

The linearity control is an interesting and important part of the vertical output system. Being a part of the cathode circuit of the tube, it controls the grid-cathode bias and hence permits the user to change the point of operation on the tube's characteristic curve. This curve, you will remember, has a linear and a nonlinear portion. Normally, one would expect the bias to be selected for linear operation because, under these conditions, the tube serves as a distortionless amplifier. On the other hand, although we have pictured the top of the trapezoidal voltage as a perfectly straight line in all our drawings, this condition is usually not true; there is always some curvature in the charge curve of a capacitor. By placing the vertical output amplifier tube on a slightly curved part of its characteristic, it is possible to balance out the opposite curvature introduced by the discharge circuit. In effect, we balance out one distortion by introducing another distortion of an opposite type.

Variations in Size and Linearity Controls

Below is another variation in the size and linearity controls. In this circuit, the vertical linearity control R4 accomplishes two functions to achieve linearity: it adjusts the voltage level of the charging circuit, and it adjusts the charging time. Notice that resistors R3 and R4 form a voltage divider, with resistor R4 as the linearity control. By moving the wiper arm of R4 closer to B+, the series capacitors C2 and C3 charge more rapidly to the positive voltage level established at the potentiometer. This rapid charge results in a nonlinear sawtooth. On the other hand, by moving resistor R4 wiper arm closer to the ground level, you increase the charge rate and thus develop a more linear sawtooth.

More Variations in Vertical Controls



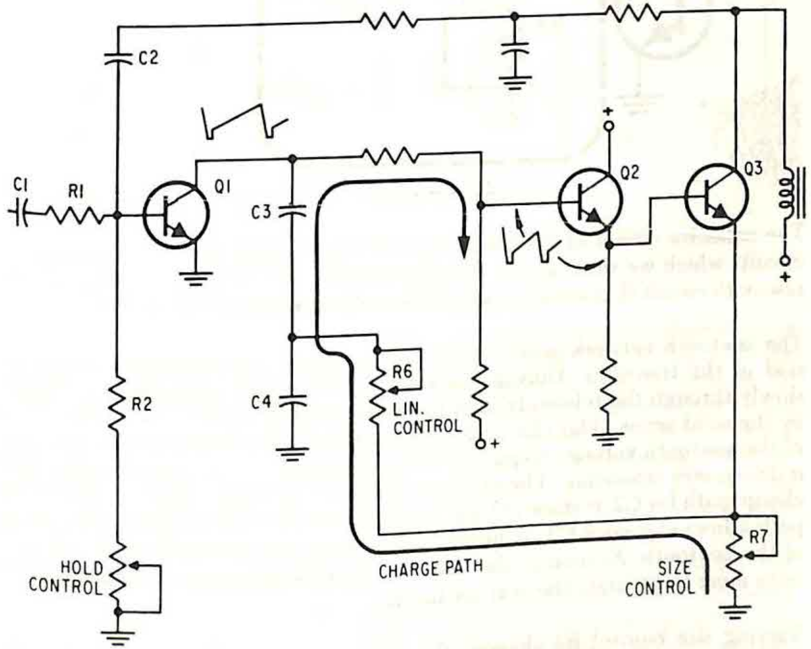
The charging path of C2 and C3 through R2 and R4 develops a sawtooth voltage across capacitor C3. Resistors R5 and R6 are in parallel with capacitor C3, and thus help to determine the size of sawtooth that we actually see at the grid of the output stage. By varying the size control R6, we therefore vary the size of the sawtooth. Resistor R6, however, serves another function in conjunction with resistor R1. By connecting R6 in series with R1, we can tap part of the dc bias voltage and negative pulse that is developed in the C1-R1-R6 path. Essentially, when capacitor C1 discharges to ground through R1 and R6, part of the dc voltage and negative signal is developed across R6. These values establish part of the negative bias at the output amplifier grid as well as the square wave at the bottom of the trapezoidal sawtooth.

A Transistor Version with Driver Amplifier

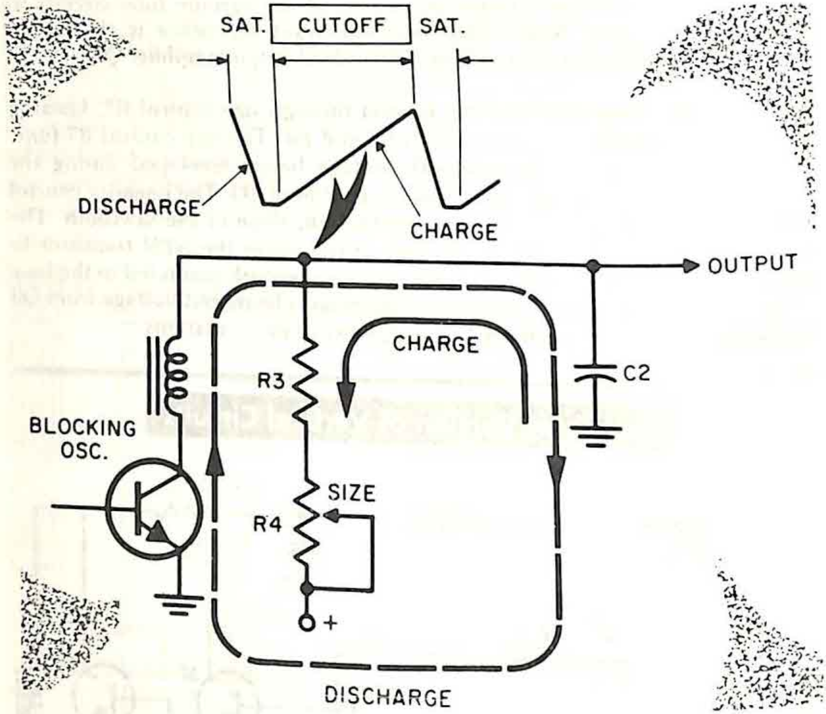
The figure below shows a transistor version of the vacuum-tube circuits we were just discussing. Notice that one significant difference is that driver amplifier Q2 is added to this configuration to feed output amplifier Q3.

The sawtooth charge path is from ground through size control R7, linearity control R6, capacitor C3, and resistors R3 and R4. The size control R7 functions to divide part of the sawtooth voltage being developed during the sawtooth development and feeds it to the emitter of Q3. The linearity control adjusts the RC charge rate to the most uniform slope of the sawtooth. The positive sawtooth developed at the base of Q2 causes the NPN transistor to conduct and thus develop an in-phase, positive sawtooth that is fed to the base of the vertical output stage Q3 for amplification. The output voltage from Q3 is coupled through the feedback loop to Q1 to sustain oscillations.

Transistor Version of Vertical Circuits



Sawtooth Output from Blocking Oscillator



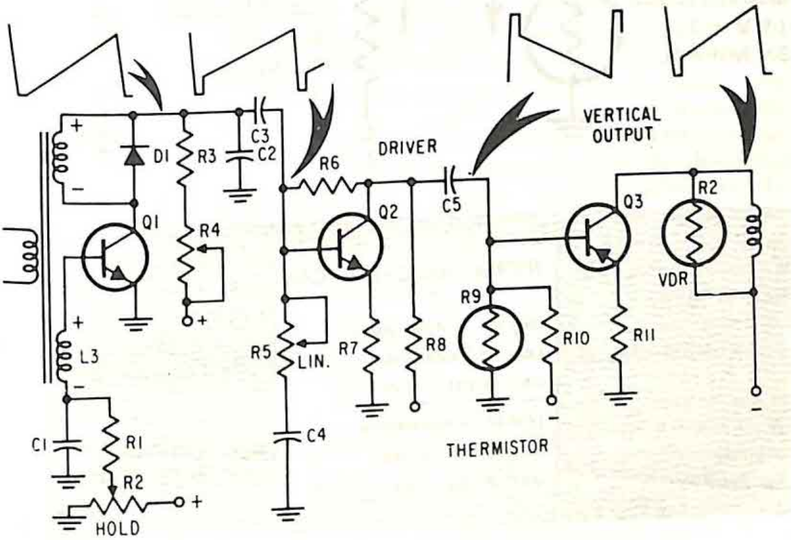
The collector circuit of the blocking oscillator contains the sawtooth shaping circuits which we show as C2, R3, and R4. This RC network is similar to the sawtooth circuit that we discussed in the vertical multivibrator circuit.

The sawtooth network generates the sawtooth rise time during the cutoff period of the transistor. During this long cutoff period, capacitor C2 charges slowly through the relatively high resistance of resistors R3 and R4, as shown by the solid arrow. This charging action gradually develops the long rise time of the sawtooth voltage. Capacitor C2 continues to charge until the transistor is driven into saturation. The saturated transistor provides a low resistance discharge path for C2 as shown by the dotted arrow. The low resistance discharge path allows capacitor C2 to quickly discharge as shown by the short fall-time of the sawtooth. As soon as the transistor cuts off again, capacitor C2 charges once more to generate the next sawtooth.

Varying size control R4 changes the charge time of C2, and thus, the amplitude of the sawtooth. A lower resistance increases the size of the sawtooth by allowing C2 to charge rapidly.

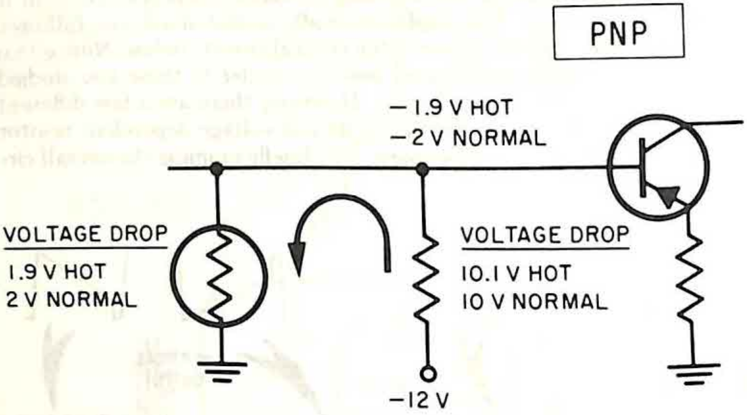
Blocking Oscillator with Driver and Vertical Output Stages

After generating the sawtooth, the blocking oscillator sends the sawtooth to the vertical amplifier stages. The amplifiers usually consist of a driver, followed by the vertical output stage as shown in the vertical circuits below. Notice that some of the circuit configurations used here are similar to those you studied earlier when we discussed multivibrators. However, there are a few different parts in this circuit, such as the thermister R9 and voltage dependent resistor VDR12. But before we discuss those parts, let's briefly examine the overall circuit operation.



The sawtooth developed across C2 couples through C3 and is reshaped into a trapezoidal sawtooth by RC network R5–C4. Resistor R5, along with the negative feed back from resistors R6 and R7 helps to correct the vertical linearity. The trapezoidal voltage is then amplified and inverted in the driver collector circuit. There, capacitor C5 couples the sawtooth to the base circuit of the vertical output stage. The voltage divider network consisting of thermister R9 and resistor R10 regulates the base bias voltage for the vertical output stage. Since the vertical output stage in this circuit uses a PNP transistor, the negative trapezoidal sawtooth causes the transistor to conduct more as the sawtooth becomes more negative. The vertical output stage thus produces a positive sawtooth which is an inversion of the sawtooth at the base. The voltage dependent resistor VDR12 in the collector circuit prevents the sawtooth voltage from developing an abnormally high inductive voltage which could destroy the transistor.

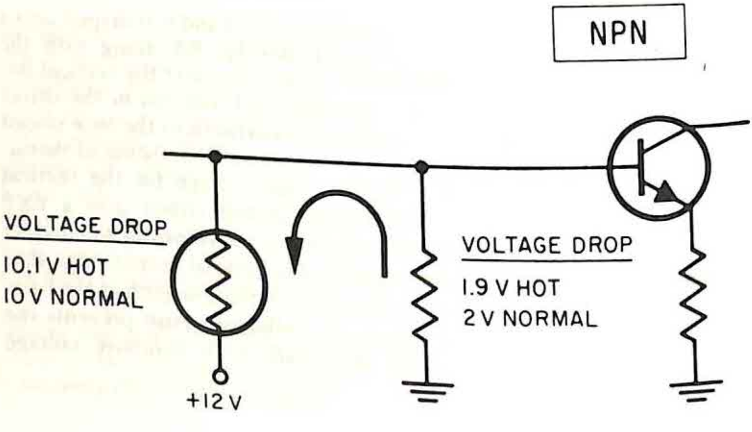
THERMISTOR ACTION



THERMISTOR OPERATION

Higher Temperature
Lowers Resistance
and drops *less* voltage

Lower Temperature
Raises Resistance
and drops more voltage



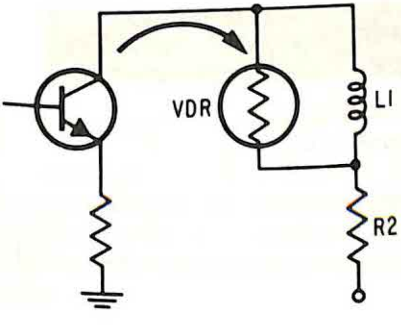
How Thermistors and VDR's Work

Thermistors and VDR's (voltage dependent resistors) are used in vertical output circuits, as well as other circuits of the television receiver, to prevent high values of current and voltage from damaging circuits. The thermistor helps to prevent transistors from conducting too much when the temperature rises. The VDR lowers its resistance as voltage across it tries to rise, and thereby maintains the same voltage. Here is how this is done.

As shown on the opposite page, thermistors are frequently used in the base circuit of NPN and PNP circuits, forming part of a voltage divider along with other series resistors. The arrows next to the voltage divider shows the direction of current. Notice that the NPN transistor circuit is grounded to the negative terminal, while the PNP transistor is grounded to the positive terminal. In both the PNP and NPN transistors circuits, the thermistor normally drops about 2 V and the resistor drops 10 V, a sum of 12V. Now when the temperature in this circuit rises, the transistor will tend to conduct more because of its thermal sensitivity. To oppose this current increase, the thermistor lowers its resistance so it will drop less voltage. You'll remember that the voltage drops in series voltage divider are proportional to the values of resistance. Thus, a smaller resistance drops a smaller voltage. This reduced value of voltage across the thermistor is also felt at the base of the transistor. Of course, a lower forward bias voltage reduces the amount of current flowing through the transistor. Reducing the transistor current this way overcomes the possible damaging effects that can result from rising temperature in the circuit.

Now let's examine how the VDR works. The voltage dependent resistor, sometimes called a varistor, lowers its resistance as the voltage across it tends to increase in value. When the resistance of the VDR decreases, the VDR will drop less voltage. Notice that since the VDR is connected across L1, the voltage appearing across the VDR branch circuit also appears across L1. Thus, the VDR senses and controls any abnormal voltage changes across L1.

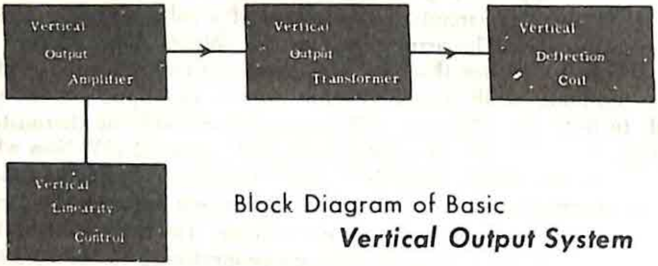
VDR ACTION



VDR OPERATION
Higher voltage drop across VDR lowers resistance of VDR
Lower resistance of VDR lowers voltage drop across VDR-L1

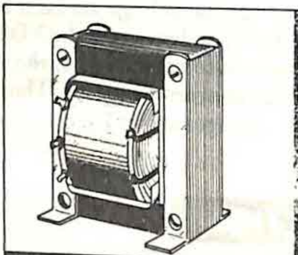
Final Stages

Vertical output amplifiers use either transistors or vacuum tubes. If the multivibrator-type oscillator circuit is used in the deflection system, the vertical output amplifier will often function as part of the multivibrator circuit. Although the vertical output amplifier stage provides feedback to previous stages both to sustain oscillations and to insure vertical linearity, it's primary function is to feed the vertical output transformer and deflection coils (illustrated below) with a suitable sawtooth.

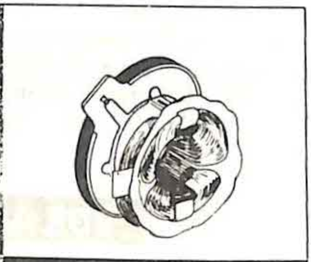

Vertical Output Amplifier
Vertical Output Transformer
Vertical Deflection Coil
Vertical Linearity Control

Block Diagram of Basic
Vertical Output System

The vertical output transformer and deflection coils shown here are typical of those you'll see in many television receivers. Of course, their size and shape may vary slightly to fit the television's physical characteristics. An important point to notice about the deflection coil is that it is constructed to fit around the neck of the picture tube. Some deflection coils provide a magnetic sleeve that also fits around the picture tube neck to help control vertical linearity.



General Appearance of Vertical Output Transformer

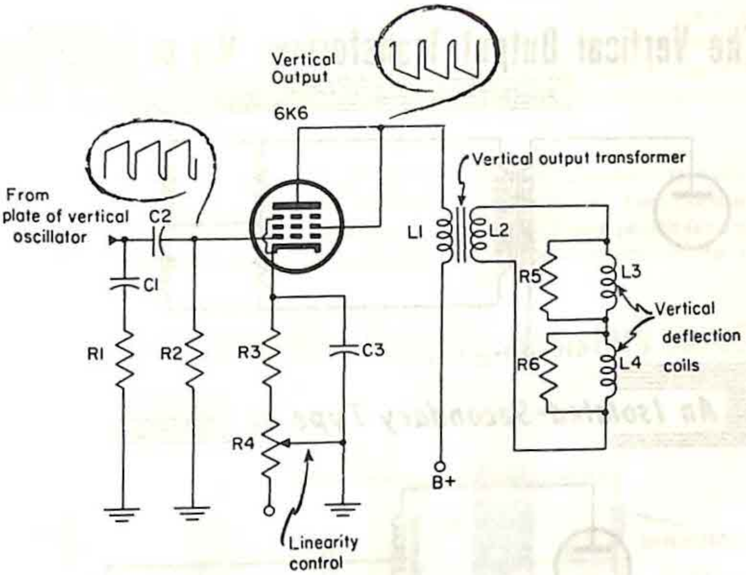


Physical Arrangement of the Vertical Deflection Coils

The voltage that appears at the plate of the vertical oscillator is of the correct waveform to produce a sawtooth current in an inductor; but, unfortunately, it does not have the required strength. This calls for further amplification—a job that is handled by the vertical output amplifier. This amplifier, together with its associated resistors and capacitors, plus the vertical output transformer, the vertical deflection coil, and the linearity control, comprise the vertical output system.

How the Vertical Output System Works

Here is the schematic view of the vertical output system with the vertical output transformer and deflection coils. As you have already noticed, the vertical output stage may be a vacuum tube or transistor. Both types of amplifier stages will, of course, produce the desired trapezoidal sawtooth voltage at the vertical output transformer. Now let's examine the output in more detail.



The Vertical Output System Schematic

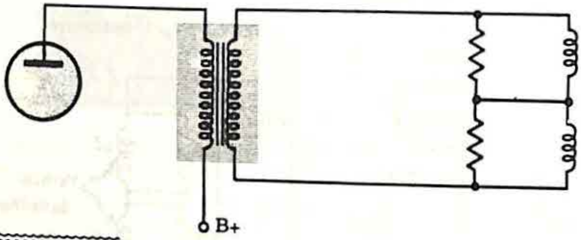
The trapezoidal voltage appears inverted and greatly amplified at the plate. This means that the voltage applied across the primary winding (L1) of the vertical output transformer has the same shape and is transferred inductively by transformer action to the secondary winding (L2). The fact that the voltage is inverted at the plate makes no difference at all since we can control the final output shape by reversing the leads to either winding of the transformer.

Thus, the trapezoidal sweep voltage is applied to the vertical deflection coils with L2 acting as the new source of sweep. These coils are formed into a yoke which fits around the neck of the picture tube. The same yoke also contains the horizontal deflection coils, as we shall discuss later.

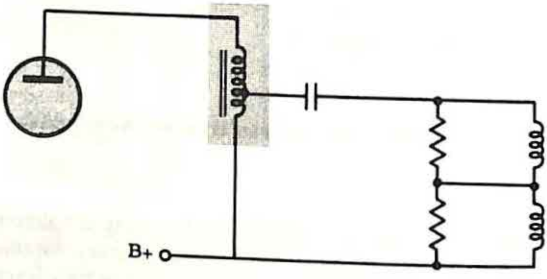
Vertical Output Transformer

Fundamentally, the vertical output transformer in the vertical output stage performs a function similar to the familiar output transformer in a radio receiver. Instead of providing an impedance match for a loudspeaker, the vertical output transformer matches the impedance of the plate circuit of the vertical output tube with the impedance of the vertical deflecting coils. This is necessary since the plate circuit impedance of the output tube is much higher than the impedance of the vertical deflecting coils. A proper impedance match assures a maximum transfer of power.

The Vertical Output Transformer May Be



An Isolated-Secondary Type or



an Autotransformer

The diagram shows an output transformer having isolated primary and secondary windings. This is not necessarily a requisite, and many modern television receivers use an autotransformer in the plate circuit of the vertical output tube. Here, the entire transformer winding is in the plate circuit of the output tube while a small portion of the winding is used to feed the vertical deflecting coils.

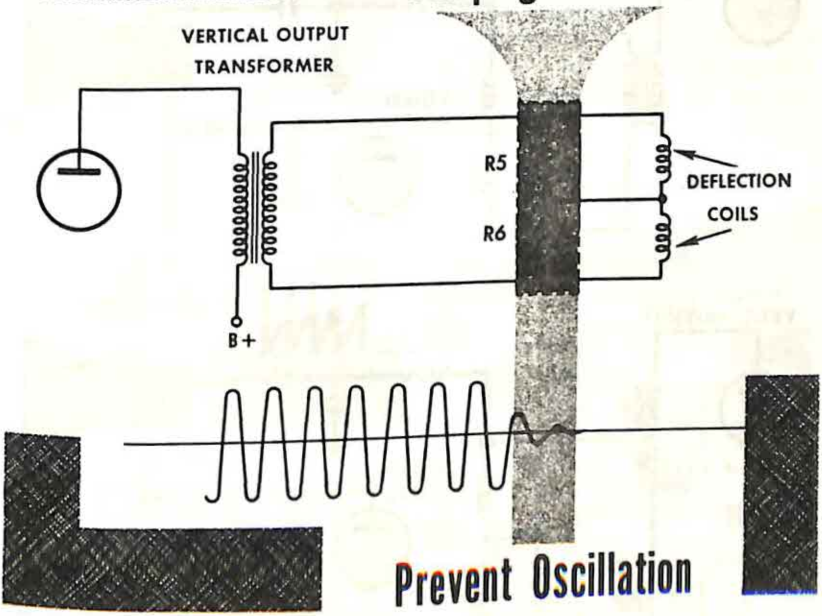
Damping Resistors

Resistors R5 and R6 are connected directly across the vertical deflection windings. In this position the resistors lower the Q of the vertical deflecting circuit and *dampen* or reduce any tendency toward oscillation in this circuit. Hence, they are given the name *damping* resistors.

The cutting off of the vertical output tube during retrace causes the magnetic field around the vertical deflecting coils to collapse. This induces a sharp pulse which could shock-excite the deflection circuit into oscillation. However, the damping resistors introduce losses in the circuit that quickly attenuate the oscillations. If one of the damping resistors were to open, the effect would be a train of oscillations in the deflecting circuit that would interfere with the normal vertical sweep and cause a distorted picture on the screen. The distortion would occur, of course, only if the oscillations were to continue into the trace portion of the sweep.

In addition to the above function, the damping resistors also serve to dampen voltage pulses induced into the vertical windings from the horizontal deflection coils that are mounted within the same yoke. These pulses are undesirable, but sometimes almost unavoidable due to the closeness of the two windings.

Damping Resistors



Prevent Oscillation

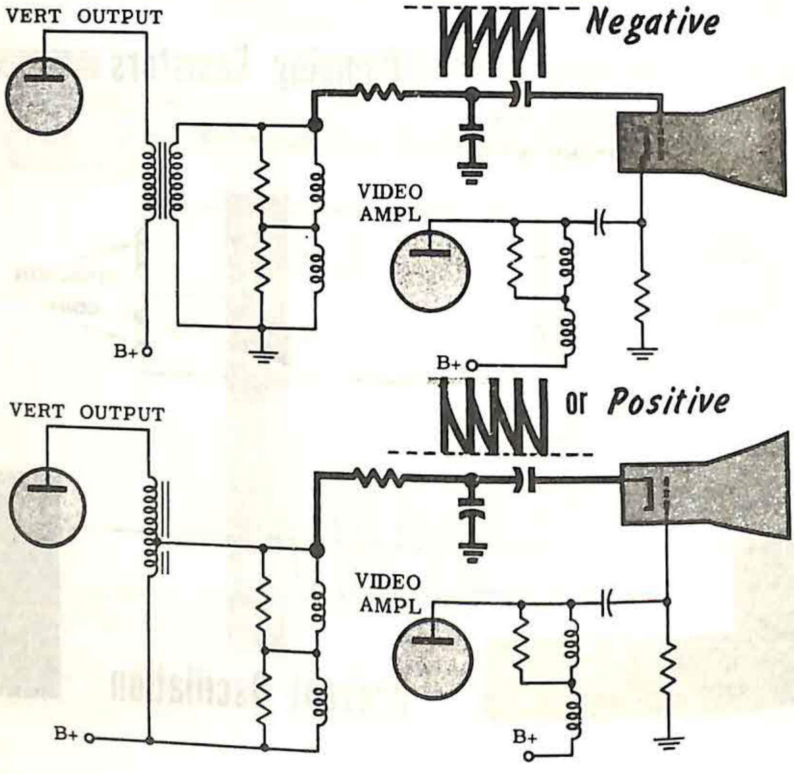
Vertical Retrace Blanking

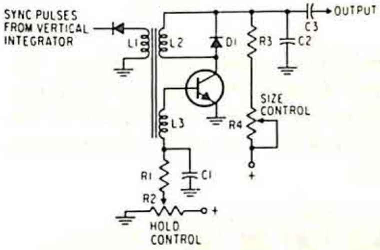
To remove the annoying vertical retrace lines visible when the brightness control is turned up, most manufacturers include in their chassis a vertical retrace blanking circuit. Fundamentally, the theory behind this circuit is to blank out or darken the picture tube screen during vertical retrace.

The general approach to this blanking is to cut off the picture tube during the time that the vertical retrace lines would normally appear. This can be done by applying a large negative pulse voltage to the control grid of the picture tube or by applying a positive pulse voltage to the cathode—each has the same effect relative to the other. Generally, it is a good idea to apply the retrace-elimination pulse to the element not used for the video input.

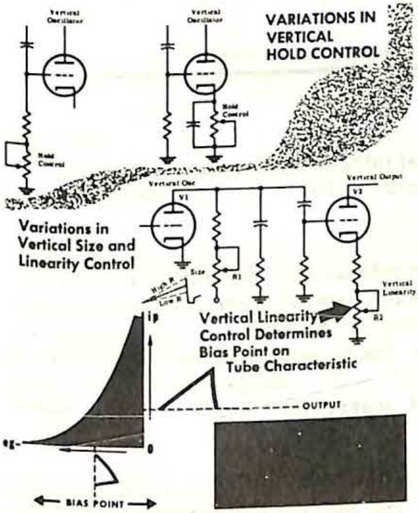
The logical place to obtain this blanking pulse is from the vertical oscillator or output circuit, with the most common takeoff point being from the vertical output transformer circuit.

THE VERTICAL RETRACE BLANKING PULSE may be



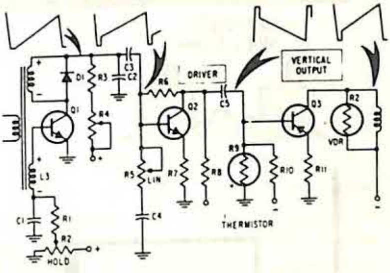


2. *The Vertical Deflection System.* The voltage that appears at the collector of the vertical oscillator is of the correct waveform, but it does not have the required strength. A vertical amplifier, together with its associated resistors and capacitors, plus the vertical output transformers, the vertical deflection coil, and the linearity control comprise the vertical output system.

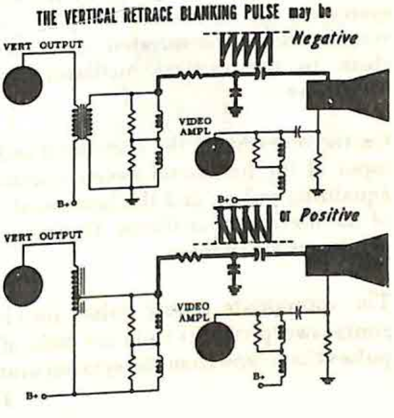

Vertical Oscillator
Hold Control
Vertical Oscillator
Hold Control
VARIATIONS IN VERTICAL HOLD CONTROL
Vertical Osc
V1
Vertical Output
V2
Variations in Vertical Size and Linearity Control
Size
R1
High R
Low R
Vertical Linearity
R2
ip
Vertical Linearity Control Determines Bias Point on Tube Characteristic
OUTPUT
eg
0
BIAS POINT

4. *Vertical Retrace Blanking.* The general approach is to cut off the picture tube during the time that the vertical retrace lines would normally appear. We do this either by applying a large negative pulse to the control grid of a positive pulse to the cathode of the picture tube.

1. *The Blocking Oscillator.* In modern television receivers, the blocking oscillator is used as a synchronizing oscillator. Feedback from collector to base is accomplished with a transformer. Any change in collector current will induce a voltage in the base circuit which will act to aid this change.



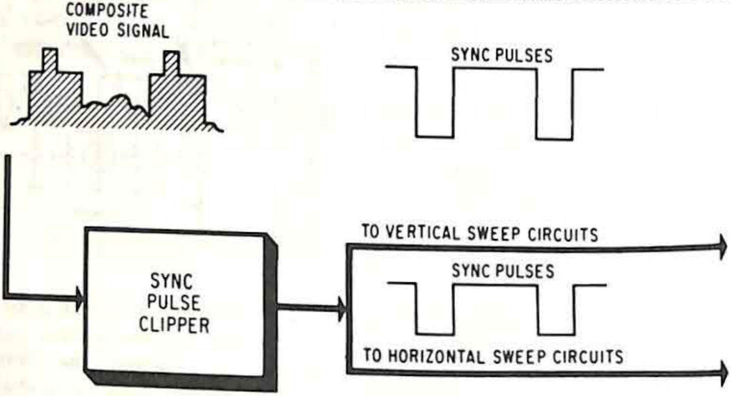
3. *The Linearity Control* is an important part of the vertical output system. By placing the vertical output amplifier tube on a slightly curved part of its characteristic, it is possible to balance out the opposite curvature introduced by the discharge circuit.



The Horizontal Sync Circuit Action

We have shown the action of the vertical sweep oscillator, and how the vertical sync pulse controls the performance of the vertical sweep oscillator. When we traced the progress of the vertical and horizontal sync signals in the preceding lesson we noted that they were divided into two paths—the vertical sweep circuit and the horizontal sweep circuit.

Block Diagram of Sync Circuits Which Feed the Sweep Circuits



The sync separator-amplifier furnishes two outputs: One which contains the vertical sync signal is fed to the vertical integrator; the other, which may be considered to be the horizontal sync signal, is fed to the horizontal sweep oscillator.

Both of these synchronizing signals have substantially the same characteristics, but the *input* systems to the vertical and horizontal sweep circuits distinguish between the pulses required by the vertical sweep oscillator and the pulses required for the horizontal sweep system. The integrator for the vertical sweep system selects the serrated vertical sync pulses, changes their shape, feeds them to the vertical oscillator, and makes the horizontal sync pulses ineffective.

On the other hand, the horizontal and vertical sync pulses are both fed to the input of the horizontal sweep system. The serrated vertical sync pulses, the equalizing pulses, and the horizontal sync pulses all contribute to the control of the horizontal oscillator. Its timing must be under control *all the while the receiver is functioning*.

The appropriate timing pulses are chosen by the input systems of the horizontal sweep circuits from the train of vertical, equalizing and horizontal sync pulses that come from the sync separator-amplifier tube.

The Differentiator

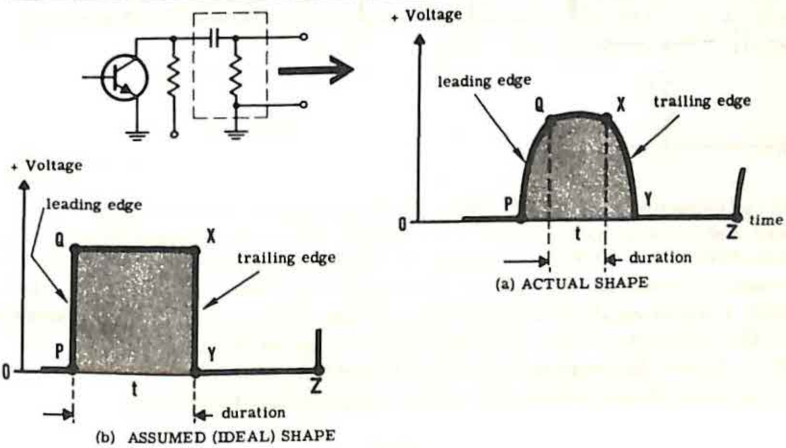
The electrical "doorway" to the horizontal sweep system is a circuit known as the *differentiator*—a simple combination of resistance and capacitance having values such that a square or rectangular pulse fed into the system will result in a *sharply peaked* output pulse. It is located in the output system of the sync circuits. The differentiator circuit is a series combination of a capacitor and a resistor, with the input voltage fed across the combination.

The output voltage is taken off across the resistor only as illustrated in the schematic. By definition a differentiator is a circuit whose *output is proportional to the rate of change of the input voltage.* The time constant of a differentiator is short compared to the cycle period of the input voltage; that is, the capacitor in the system can be charged and discharged more rapidly than the input signal can change polarity.

The diagram shows an actual and ideal square-wave pulse, the ideal having sides that are perfectly straight. Straight sides correspond to *zero rise time;* that is, zero time for the rise in amplitude to maximum. While such a pulse cannot be obtained in practice, it lends itself well to simplified explanations. The pulse is shown as a positive waveform to indicate that all its changes occur in the positive region.

At point P the pulse amplitude is zero, and it is assumed to rise to Q, its maximum value in zero time. After Q has been reached the voltage of the pulse remains constant for period t represented by the horizontal distance Q-X. Then the voltage falls rapidly to zero or point Y. The time interval X-Y corresponds to the fall time and this, too, is assumed to be zero.

ACTUAL and IDEAL PULSE SHAPES



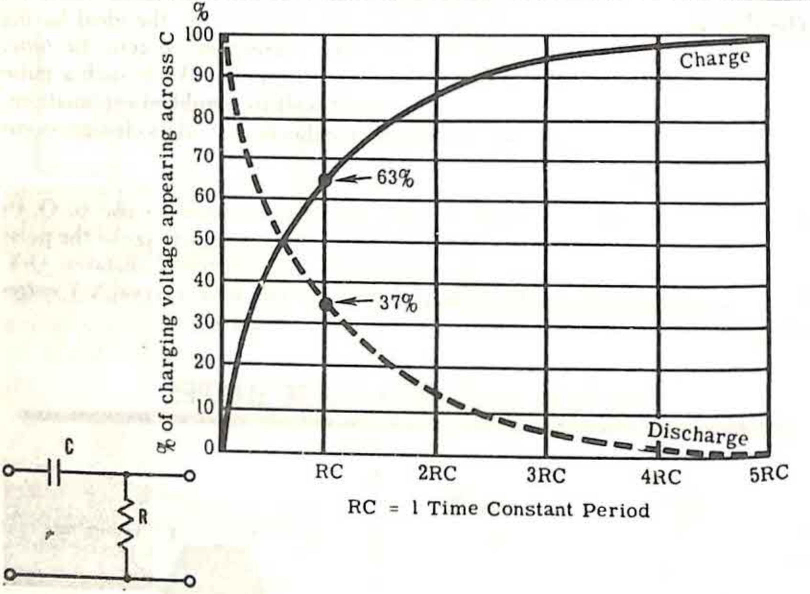
(a) ACTUAL SHAPE

(b) ASSUMED (IDEAL) SHAPE

RC Time Constant

The time constant of an RC circuit is defined as the product of the capacitance in farads and the resistance in ohms. Basic electricity teaches that when voltage is applied to a capacitor a definite time must pass before the voltage built up across the capacitor by the charging current equals the applied voltage. The higher the resistance in the circuit (and the larger the capacitance), the longer will be this period of voltage buildup. In a similar manner, the higher the resistance (and the larger the capacitance), the greater will be the time required for the capacitor to discharge. By definition the time constant is the time required for the voltage to build up to approximately 63% of the applied voltage.

Charge and Discharge Curves



If the capacitance of an RC differentiator is 0.002 μF [0.000000002 F (farad)] and the resistor has a value of 10,000 Ω, the time constant in seconds is 0.000000002 × 10,000 or 0.00002 sec. This time period is equal to the time needed to complete 1 Hz of a 50-kHz signal or 1/0.00002 = 50,000 Hz. Hence such a circuit would be a *short-time-constant* differentiator for frequencies of 10,000 Hz or less, and a *long-time-constant* circuit for frequencies of 50,000 Hz or higher. By juggling the value of C and R it is possible to arrange short- or long-time-constant differentiators for voltages of any frequency.

Action of Differentiator

What happens when a square-wave voltage pulse is applied to a short-time-constant differentiator? Suppose we assume the ideal pulse illustrated before. The sharply rising leading edge (P-Q) corresponds to a very rapidly changing voltage. This produces a sudden rush of charging current through R and C. With R of low resistance and C of small capacitance, the capacitor charges rapidly to the peak value. The charging current being high, a large voltage-drop appears across R while the current is flowing.

The voltage across the capacitor reaches its maximum value rapidly, hence the charging current ceases. With no further change in input voltage, the capacitor charging current falls to zero. With diminishing current-flow through R, the voltage-drop across R gradually falls to zero. Thus the sudden charging of the capacitor causes a very sharply peaked pulse to appear across R.

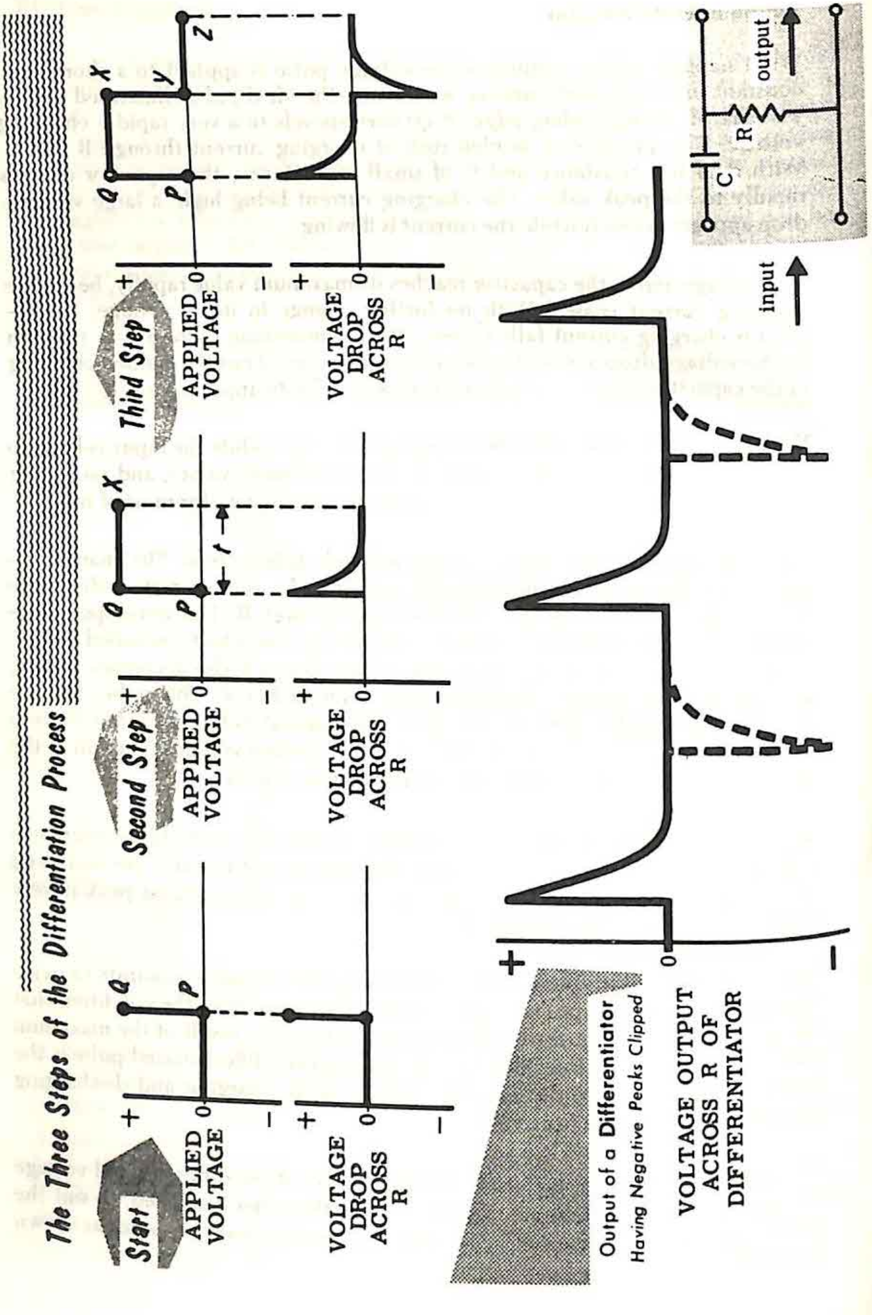
With the voltage drop across R having fallen to zero while the input voltage to the differentiator circuit was constant (at its maximum value), and no further current flows through R, the voltage across R remains zero for most of time *t*.

Then the applied square-wave voltage suddenly falls to zero. The charged capacitor discharges in the differentiator circuit and a sudden rush of discharge current takes place in the *opposite* direction through R. This develops a large voltage drop across R with a polarity *opposite* to that which prevailed before. As the discharge current decreases, the voltage across R also decreases. Hence, a negative pulse appears during the time interval X-Y-Z. This pulse, like the previous one reaches zero shortly after the applied voltage reaches its zero value, and remains at zero until the next rise in applied voltage. At point Z, the next P-Q rise is about to begin, thus repeating the process.

So it is that a differentiating circuit produces a pulse for each abrupt *change* in voltage applied to the circuit. Because the constants of R and C are small and the change in applied voltage is very abrupt, the differentiated peak is very pointed and of very short duration.

Note that the peak-to-peak value of the differentiated pulse amounts to twice the peak value of the applied input voltage. This arises from the condition that the amplitude of the positive differentiated pulse is the result of the maximum charging current, and the amplitude of the negative differentiated pulse is the result of the maximum discharging current—both charging and discharging currents having similar peak values.

Although both the positive or the negative peaks of the differentiated voltage can be used, they seldom are. Usually one or the other is clipped, to suit the particular circuit needs. In our case only the positive peaks are used, as shown in the illustration opposite.



The Three Steps of the Differentiation Process

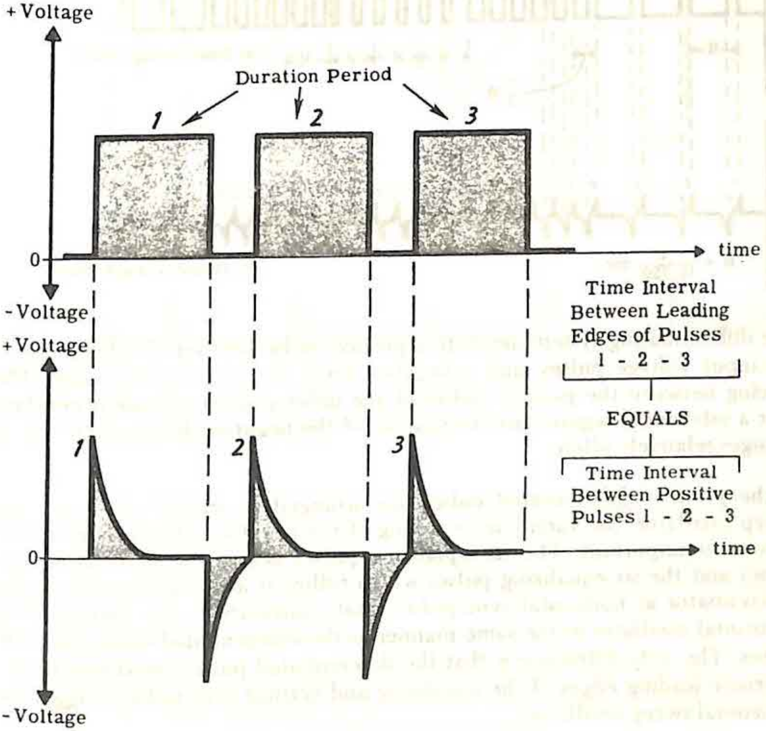
Start
APPLIED VOLTAGE
VOLTAGE DROP ACROSS R
Second Step
Third Step
+
0
−
Q
P
X
Y
Z
t
Output of a Differentiator
Having Negative Peaks Clipped
VOLTAGE OUTPUT ACROSS R OF DIFFERENTIATOR
C
R
input
output

The Effect of the Input Pulse Shape on the Differentiated Output

We have shown the short-time-constant differentiated output for a square-wave input voltage. Suppose that the input voltage pulse is of relatively long duration with short zero-voltage intervals.

The differentiating action does not change. The negative pulse of the differentiated output for the trailing edge of the input voltage is very close to the positive differentiated pulse due to the leading edge of the adjacent input voltage pulse. The time relationship, however, between the leading edges of the input voltage pulses and the positive differentiated pulses has not changed, nor has it changed between the trailing edges of the input voltage pulse and the negative differentiated pulses.

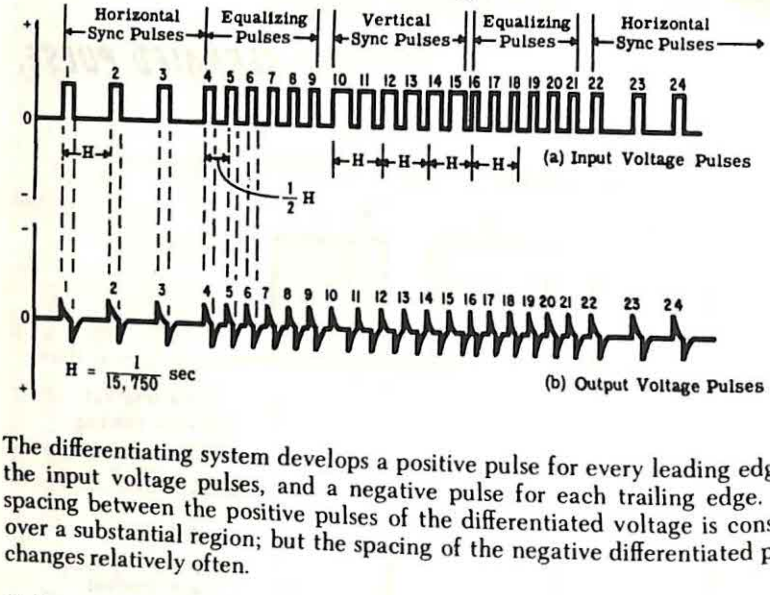
HOW THE DIFFERENTIATOR REACTS TO THE VERTICAL SERRATED PULSE.


+ Voltage
Duration Period
1
2
3
0
time
- Voltage
+ Voltage
Time Interval Between Leading Edges of Pulses 1 - 2 - 3
EQUALS
Time Interval Between Positive Pulses 1 - 2 - 3
1
2
3
0
time
- Voltage

Input and Output Voltage in the Differentiator

Let us now apply a variety of voltage pulses to a differentiating network, as for example equalizing, vertical sync and horizontal sync pulses. Three kinds of pulses are shown here. All are rectangular but some differ from the others in duration. The equalizing and the vertical sync pulses have adjacent leading edges which are only one-half horizontal line apart; that is, they have a frequency of 31,500 Hz. However, *alternate leading edges* correspond to full horizontal line separation of a frequency of 15,750 Hz. The horizontal sync pulses have adjacent leading edges that are timed for 15,750 Hz; that is, they are a full line apart so that they will trigger the horizontal oscillator once every 63 μsec (the time for the picture tube beam to complete its excursion to the right-hand edge of the tube and return to the left-hand side).

Input and Output PULSE Voltage in the Differentiator



The differentiating system develops a positive pulse for every leading edge of the input voltage pulses, and a negative pulse for each trailing edge. The spacing between the positive pulses of the differentiated voltage is constant over a substantial region; but the spacing of the negative differentiated peaks changes relatively often.

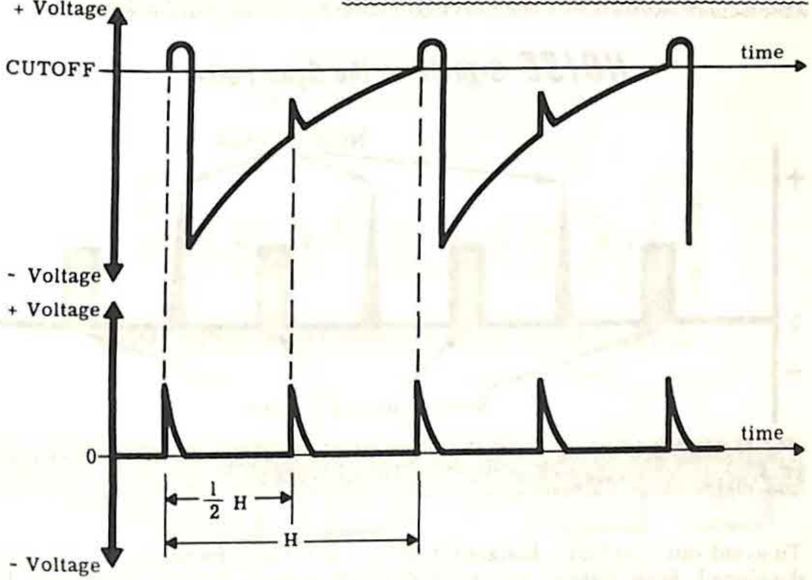
If the *positive differentiated* pulses are arranged to *trigger* the horizontal sweep oscillator, the variations in timing of the negative differentiated pulses become unimportant. The six equalizing pulses before the six vertical sync pulses and the six equalizing pulses which follow it are as acceptable to the differentiator as horizontal sync pulses, and contribute to the timing of the horizontal oscillator in the same manner as the differentiated horizontal sync pulses. The only difference is that the differentiated pulses (produced by the *alternate* leading edges of the equalizing and vertical sync pulses) trigger the horizontal sweep oscillator.

Triggering Action

If the differentiated pulse corresponding to the leading edge of horizontal sync pulse 1 triggers the horizontal oscillator, then the differentiated pulses for leading edges of equalizing pulses 4, 6 and 8, the leading edges of vertical sync pulses numbered 10, 12, and 14 and the leading edges of equalizing pulses numbered 16, 18, and 20 will trigger the oscillator, after which time the horizontal sync pulses again take over.

Triggering in a Multivibrator

showing lack of response to half-line triggering pulses.



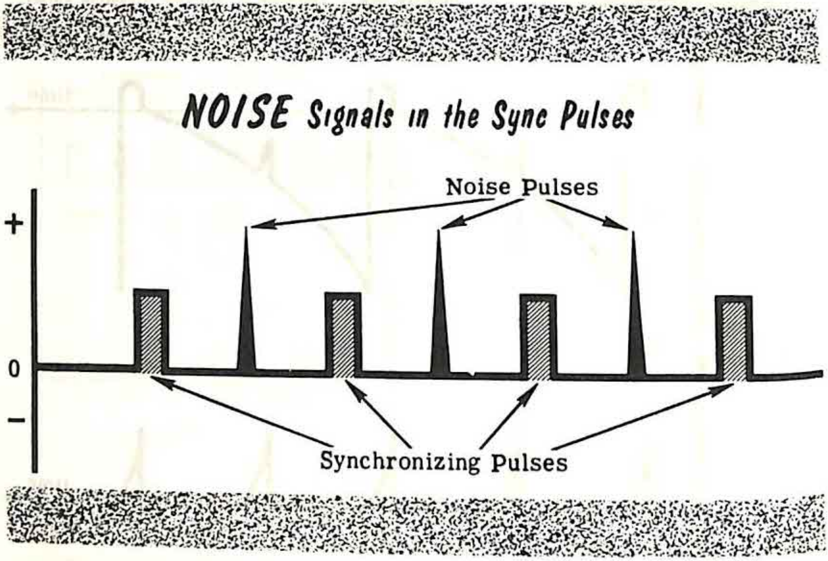
The fact that the equalizing and the vertical sync pulses produce positive-polarity differentiated pulses at half-line intervals (pulses 3, 5, 7, etc.) also does not result in improper triggering of the horizontal oscillator because the circuit conditions in the oscillator are such as not to respond to these positive pulses from the differentiator.

Although most modern day television receivers do not use direct triggering of the horizontal sweep oscillator by the differentiated voltage received from the sync circuits, it is important to understand this action.

Horizontal AFC

The control of the horizontal sweep oscillator frequency by direct application of differentiated pulses would be successful if it were not for the random noise pulses that are present in the sync signals. These noise pulses often cause untimely triggering of the oscillator.

Inasmuch as the sweep oscillator cannot distinguish between various voltages applied to it for synchronizing purposes, undesired signals of this variety can make the picture-tube electron beam move out of step with the electron beam in the television camera. The result is a very unsteady picture; in fact, a picture of this kind cannot be deciphered at all.


NOISE Signals in the Sync Pulses

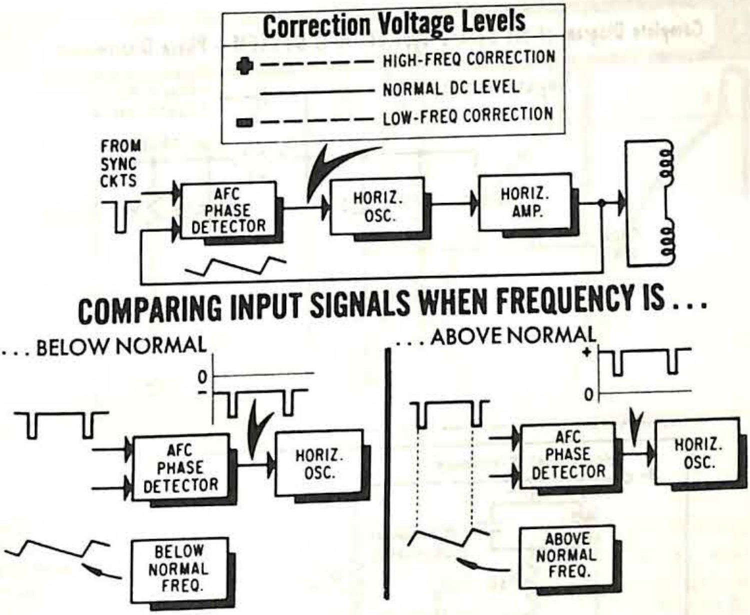
To avoid this possibility, horizontal AFC or *automatic frequency control* was developed. Such systems are standard in all modern television receivers. In AFC systems the sync pulses are used strictly for reference purposes; that is, they are *compared* electronically with either the voltage generated by the horizontal sweep oscillator, or with the sweep voltage which actually moves the electron beam in the horizontal direction across the picture tube screen.

If the horizontal sweep oscillator output is not timed correctly (frequency and phase) with the reference sync pulses, a dc *correction* voltage is generated in a detector circuit. This voltage either raises or lowers the frequency of the sweep oscillator, as necessary. If the two voltages are correctly timed, the (detector) circuit "idles," causing no change in conditions.

Block Diagram of One Type of Horizontal AFC System

The horizontal AFC system is designed to keep the horizontal oscillator "on frequency." It does this by using an AFC phase detector circuit to compare the frequency of the horizontal sawtooth with that of the incoming horizontal sync pulses. Usually, the detector compares negative sync pulses with the sawtooth waveforms from either the horizontal amplifier or horizontal oscillator.

Briefly, here's how it works. If the sawtooth frequency changes, the AFC phase detector reacts by developing a "correction" dc voltage that it feeds to the horizontal oscillator. Thus, if the sawtooth frequency drifts to a below-normal frequency, the phase detector develops a negative dc correction voltage that will raise the horizontal oscillator frequency to normal. On the other hand, a higher-than-normal sawtooth frequency develops a positive dc correction voltage that lowers the horizontal oscillator frequency to normal.

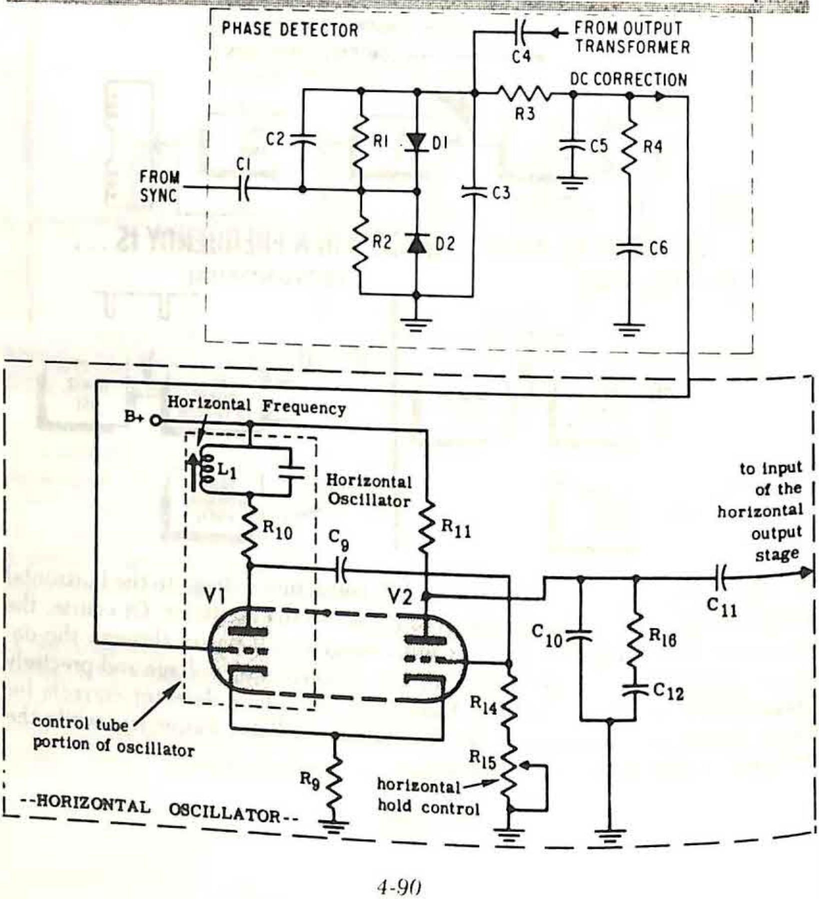


The AFC phase detector not only sends a correction voltage to the horizontal oscillator, but it also couples the sync pulses to the oscillator. Of course, the horizontal sync-pulse frequency is not changed as it passes through the detector; instead, they simply "ride" on the dc correction voltage and precisely trigger the horizontal oscillator. Essentially, the phase detector corrects for coarse frequency variations in the horizontal oscillator frequency, while the sync pulses correct for slight variations.

A Brief Look at the AFC Phase Detector—Horizontal Oscillator Circuits

The AFC phase detector circuit shown here is one of the most common types used in horizontal AFC systems. This phase detector consists of two solid-state diodes, D1 and D2, with their cathodes connected together. These two diodes compare the sawtooth voltage that's coupled to the anode of D1 while the sync pulse voltage is coupled to the cathodes of D1 and D2. If the sawtooth frequency changes, the detector will develop a dc correction voltage that it feeds to the grid of the horizontal oscillator tube V1. This correction voltage alters the bias which, in turn, alters the frequency of the oscillator. The cathode-coupled multivibrator circuit shown here is only one of several types that you'll see used as the horizontal oscillator. Other oscillators are variations of basic oscillators such as the blocking oscillator and Hartley oscillator. In the lessons that follow, we will discuss some of the frequently used types of horizontal oscillators. But for now, let's analyze the operation of the cathode-coupled multivibrator and its frequency control.

Complete Diagram of the Second Type of AFC SYSTEM – Phase Discriminator

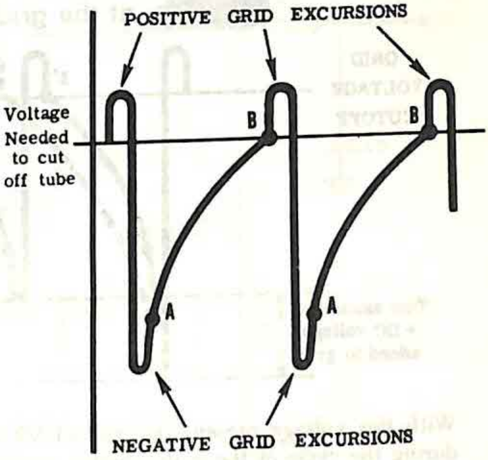


Phase Detector AFC (cont'd)

The oscillator is an ordinary cathode-coupled multivibrator with one additional feature. The presence of L1 in the plate circuit of one of the triodes allows a certain amount of phasing adjustment, as will be indicated later. Otherwise, the circuit is perfectly straightforward. With the horizontal hold-control potentiometer in its proper position, the output frequency of the multivibrator is approximately 15,750 Hz. Now we shall see how a positive or negative dc control voltage applied to the grid of the controlled triode governs the frequency of the multivibrator between limits.

When a multivibrator functions without outside "interference" from a controlling stage it produces a waveform something like this:

Grid Voltage Waveform of the Free-running Multivibrator without Interference



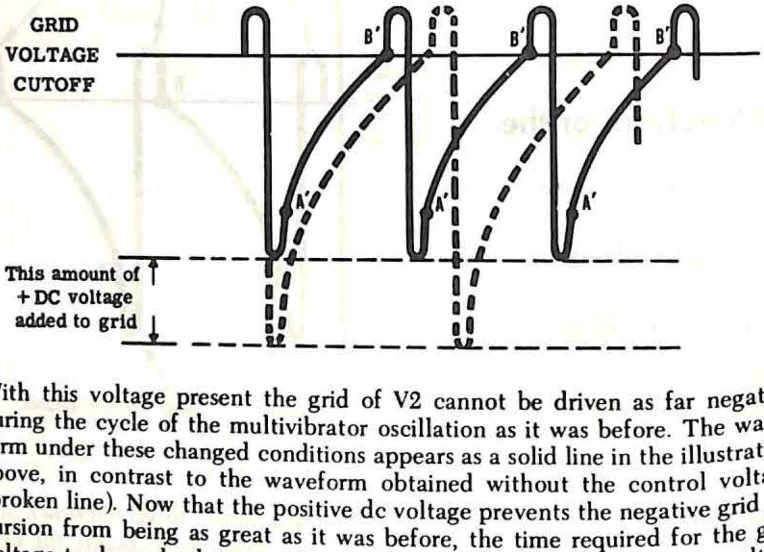
In normal oscillation, the grid of the multivibrator tube is driven far down into the region below cutoff. The time interval which must elapse before the next positive pulse is obtained from the multivibrator is governed by the length of time needed for the grid voltage to decay back to cutoff (over the path A to B, in the diagram). Thus, the frequency of the multivibrator—which we want to be exactly 15,750 Hz—depends to a great extent upon this decay time.

While the circuitry of multivibrators may vary slightly, the decay time is usually determined by the action of a resistor and capacitor in series. Thus, in effect, the time constant of an RC network is involved. If the value of R and C is relatively small, the decay will be rapid, and it will take only a short period of time for the voltage swing to climb to the cutoff level. If the RC value is large, the decay time will be slow, and the time taken for the voltage to reach cutoff level will be long.

Action of the Control Voltage

Consider now that a negative potential of a few volts is applied to the grid of the left-hand triode section, V1. This causes a decrease of the plate current of V1 which in turn reduces the voltage drop across the common cathode resistor R9; that is, the top of R9 becomes less positive with respect to B− than it had been before the application of the new minus voltage on the grid of V1. Now we turn our attention to V2. Since its cathode is connected to the top of R9, the voltage at this point becomes slightly less positive than it was previously. When a cathode becomes less positive this is the same thing as having the grid of the same tube go *positive*. Hence, we see that a negative voltage applied to the grid of V1 causes a corresponding positive voltage to appear at the grid of V2.

Action of *Control Voltage* at the grid of the Multivibrator

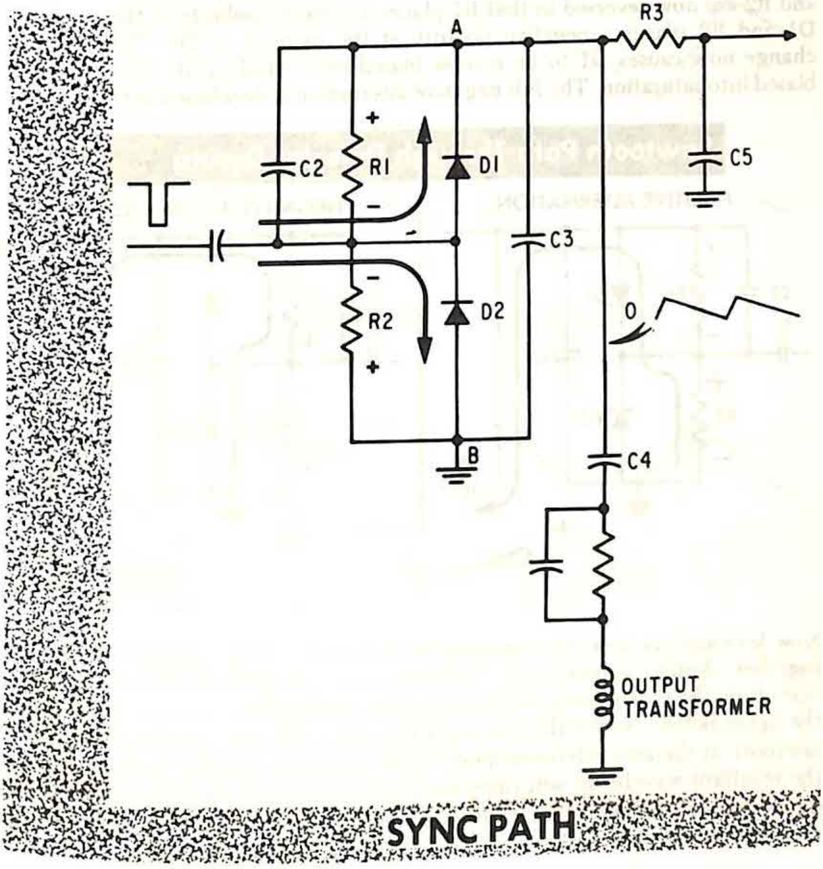


With this voltage present the grid of V2 cannot be driven as far negative during the cycle of the multivibrator oscillation as it was before. The waveform under these changed conditions appears as a solid line in the illustration above, in contrast to the waveform obtained without the control voltage (broken line). Now that the positive dc voltage prevents the negative grid excursion from being as great as it was before, the time required for the grid voltage to decay back to cutoff is smaller (A′ to B′) so that the next multivibrator cycle begins substantially earlier. In this way, *the frequency of the horizontal oscillator is increased by applying a negative control voltage to the grid of V1.*

Should the control voltage be positive in polarity, the opposite effect occurs. The grid of the right-hand triode, V2, may now be driven further below cutoff and the time needed for its grid to come back to conduction again is extended. Hence, fewer cycles are obtained per second and the *frequency is lowered when the dc control voltage is positive.*

The Phase Detector

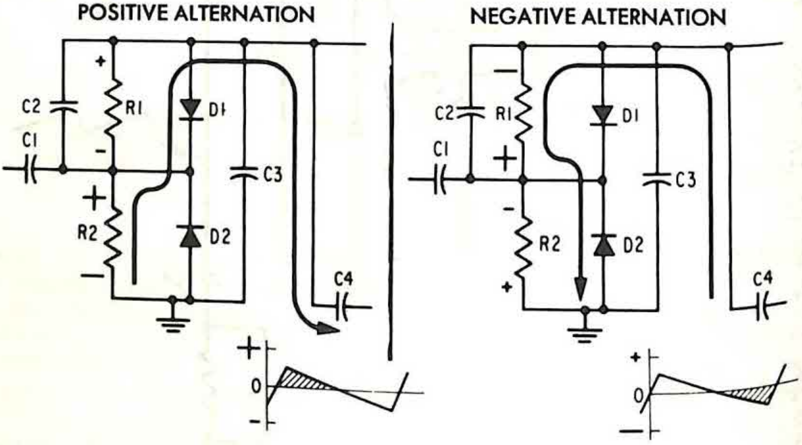
We'll begin our analysis of this stage by first tracing the separate signal paths for the sync pulses and the sawtooth, and then tracing their composite effects in the circuit. The negative sync pulses from the sync amplifier are coupled through capacitor C1 to the cathodes of diodes D1 and D2. Each time a negative pulse arrives, it causes current from C1 to divide through resistors R1 and R2. Since the polarity of voltage developed across each resistor forward biases their respective diodes, each diode acts like a short. Thus, most of the current is shunted through the diodes rather than through R1 and R2. Since the configuration of R1 and D1 equals R2 and D2, each configuration develops an equal voltage drop. Furthermore, since the polarity across R1-D1 opposes the polarity across R2-D2, the values of voltage drops oppose each other, also. Thus, the value of voltage from the anode of D1 to ground equals zero volts.



The Phase Detector (cont'd)

Now let's examine the sawtooth current path. The sawtooth generated at the horizontal output circuit is fed back through capacitor C4 to the detector network. Since capacitor C4 finds a charge and discharge path to ground, through the detector network, the sawtooth voltage rises above and below the zero volts reference level. Thus, when the sawtooth alternates in a positive direction, the charge path is from ground through resistors R1 and R2 toward capacitor C4. During this charging path, the polarities developed across R1 and R2 are such that R2 places a positive polarity at the cathode of D2, and R1 places a positive polarity at the plate of D1. Thus, diode D2 is reverse-biased into cutoff and diode D1 is forward-biased into saturation. Since D1 acts as a short across R1, the value of voltage across R1-D1 is zero. But since D2 acts as an open circuit across R2, the full positive voltage alternation is developed across R2-D2. During the next alternation, the polarities developed across R1 and R2 are now reversed so that R1 places a negative polarity at the anode of D1 and R2 places a negative polarity at the cathode of D2. This polarity change now causes D1 to be reverse biased into cutoff, while D2 is forward biased into saturation. The full negative alternation is developed across R1-D1.

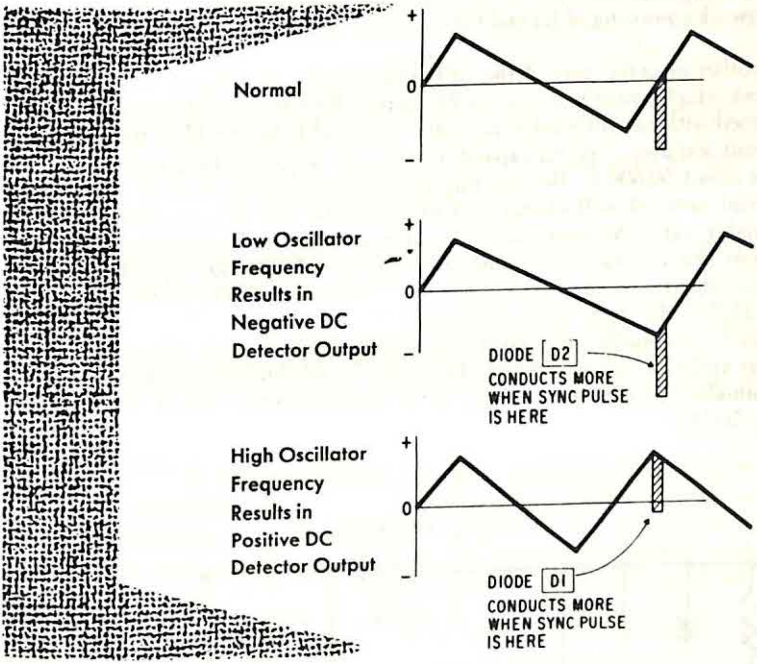
Sawtooth Path Through Detector During . . .



Now let's analyze how the combination of the sync pulses and sawtooth work together during normal and "off-frequency" conditions. During normal operation, the sync pulse and sawtooth arrive at the phase detector as shown in the figure below. Notice that the negative sync pulse rides on the slope of the sawtooth at the zero reference level. If the sawtooth remains "on frequency," the resultant waveforms will cause each diode circuit to conduct equally. The dc correction voltage that results across the phase detector network is, therefore, about zero volts.

The Phase Detector (cont'd)

Now let's consider what happens to the superimposed waveform when the sawtooth frequency is *too high*. Since the sync pulses remain fixed, occurring every 63 μsec, the slope of the sawtooth will shift to a point slightly before its normal position. Essentially, the shifted sawtooth causes the sync pulse to ride at a high position on the slope. When this occurs, the conduction of the two diodes becomes unbalanced. Since the sync pulse moves in a positive direction on the sawtooth, the phase detector conducts more during the positive sawtooth alternations. Thus, the resulting waveform produces a greater positive voltage across diode network R2-D2. The overall effect is that a positive dc correction voltage is fed back to the oscillator grid, returning the horizontal oscillator frequency to normal.


Normal
+
0
-
Low Oscillator Frequency Results in Negative DC Detector Output
+
0
-
DIODE D2 CONDUCTS MORE WHEN SYNC PULSE IS HERE
High Oscillator Frequency Results in Positive DC Detector Output
+
0
-
DIODE D1 CONDUCTS MORE WHEN SYNC PULSE IS HERE

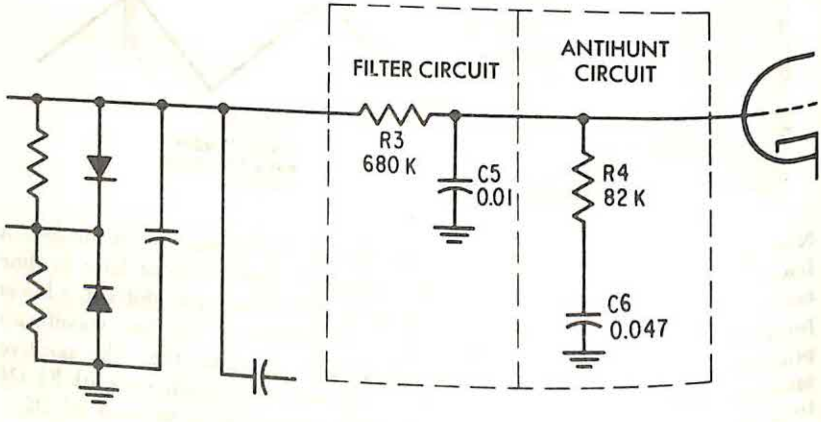
Now let's consider what happens when the sawtooth frequency is *too low*. A lower sawtooth frequency causes the sawtooth slope to occur later in time compared to the sync pulse. The sync pulse, therefore, now shifts to a lower position on the sawtooth slope. The combination of the two waveforms produces a net voltage which is now greater in value than the positive sawtooth alternation. The overall effect now causes the diode network R1-D1 to develop a greater negative voltage drop than across diode network R2-D2.

AFC System—Antihunt Circuit

During the operation of an AFC system, the horizontal oscillator may change frequency by as much as 400 Hz above or below the normal 15,570 Hz. A typical range of dc correction voltage developed in the AFC detector is about −4 V to +4 V. Thus, if the horizontal oscillator rises to about 16,000 Hz, the phase detector will develop about a *positive* 4 V. On the other hand, a below-normal frequency of 15,400 Hz would be corrected by a *negative* 4 V. In the example we have used, the frequency-to-voltage correction is about 100 Hz/V. In more sensitive oscillator circuits, smaller values of voltage will produce greater frequency changes.

The rate of correction, however, is not instantaneous. If it were, the AFC system would be correcting the oscillator for every momentary interference and unwanted noise pulse. To overcome this instantaneous reaction, a filter network consisting of R3 and C5 is used to function as a time delay.

Another essential part of the AFC phase detector circuit is the antihunt network which consists of a series RC circuit, R4-C6. This RC combination is designed with carefully selected values of R and C to provide a time constant of about 500 μsec. Typical capacitor values are about 0.01μF, and resistor values are about 50,000 Ω. By selecting the appropriate values of R and C, the antihunt network will charge and discharge to the dc correction voltage at a suitable rate. Without the antihunt network the dc control voltage would cause the oscillator to swing not only to 15,570 Hz, but also beyond it. Thus, the oscillator may swing from 15,700 to 15,800 Hz, instead of locking-in at 15,750 Hz. As a result, the phase detector without the antihunt network would continually sense error frequencies, and would try to correct for them. This action is called *hunting*. By using the antihunt network, the RC circuit gradually changes the voltage to the value required to lock the oscillator to 15,750 Hz.



Another Type of Horizontal AFC System—Pulse-Width or Synchroguide

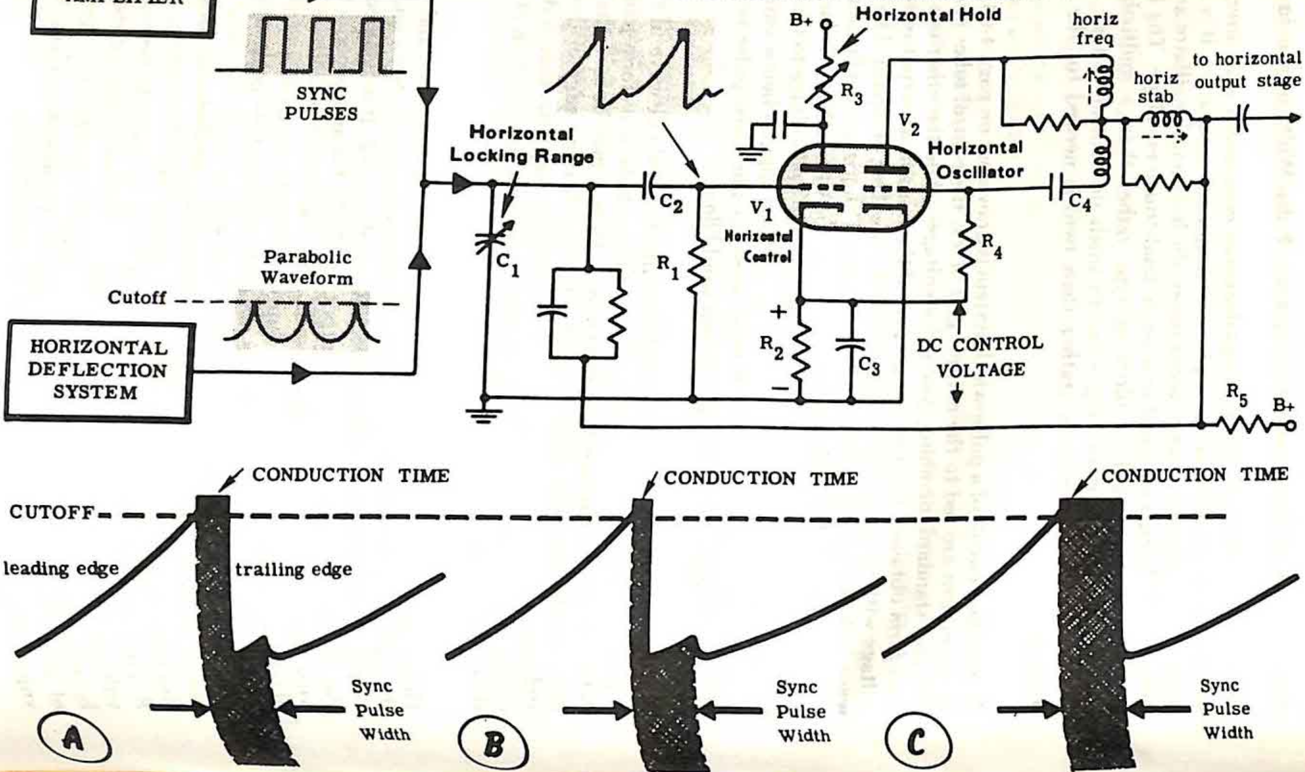
This extremely popular AFC system dispenses completely with discriminators, discriminator transformers, and phase or frequency comparers. It is more economical initially and requires fewer tubes, the horizontal oscillator and control tube usually being contained in a single dual-triode envelope. The horizontal oscillator is customarily a blocking type rather than a multivibrator because this circuit is more responsive to small dc control voltage variations and because only one tube (rather than two) is needed for the oscillator section.

A simplified circuit of a pulse-width system is drawn out on page 4-98. Two sets of waveforms are fed to the control grid of V1, the control tube: one of these provides standard incoming sync pulse voltages while the other is a *parabolic waveform* obtained by combining a part of the horizontal output system sweep voltage with varying plate voltages from the blocking oscillator. The parabolic wave is shown emerging from the block labeled "horizontal deflection system" in the diagram." The cathode biasing resistor for V1 is sufficiently large so that the incoming parabolic waveform just drives the grid voltage to the point before conduction begins; that is, the tube is biased slightly below cutoff for the peaks of the parabolic waves. If there were no additional pulse voltages applied to the grid of V1, no plate current would flow.

As the sync pulses arrive, they combine with the parabolic wave. If the system is perfectly synchronized, the peaks of the parabolic waveform join the sync pulses at the coincidence time shown in A. Here it may be seen that the sync pulse combines partly with the gradually rising leading edge of the parabola and partly with the trailing edge. At the leading edge, the tube is driven into conduction for an interval represented by the horizontal portion of the pulse above the cutoff line.

Hence, plate current flows in V1 during the interval shown in A and, on its way through cathode resistor R2, produces a voltage drop such that a small positive voltage is applied to the grid of blocking oscillator V2. It is assumed that now the horizontal oscillator has an output of 15,570 Hz and is perfectly phased with the sync pulses. In other words, this small control voltage keeps the blocking oscillator on frequency. Suppose that the horizontal oscillator now tends to speed up. As a result, the parabola will reach its peak sooner than it should; but the transmitted sync pulse still will arrive at the same time. This moves the pulse closer to the trailing edge of the parabola and kicks the control tube into the conducting region for a shorter time than before, as shown in *B*. This causes the average plate current of V1 to decrease. In consequence, the voltage drop, across R2 also decreases and the control voltage at the grid of V2 becomes less positive than before. Applying a *less positive* voltage to the grid of a blocking oscillator causes its frequency to *decrease*. Thus, the control voltage brings the blocking oscillator back to 15,750 Hz.

A THIRD Type of HORIZONTAL AFC SYSTEM (Pulse Width or Synchroguide)



Pulse-Width or Synchroguide AFC (cont'd)

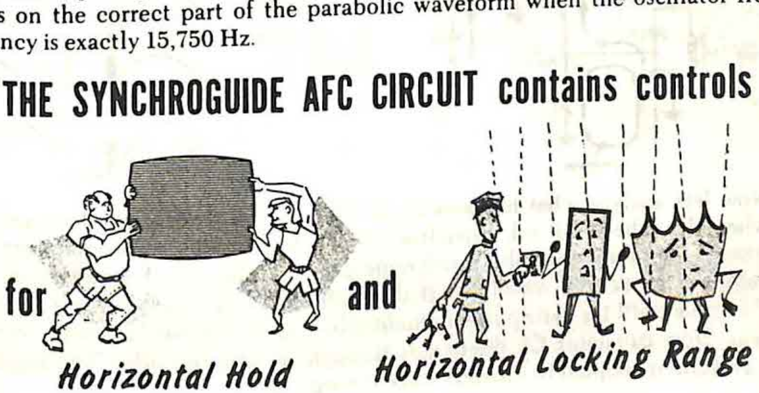
When the horizontal oscillator slows down due to some voltage or circuit change, the condition shown in *C* is encountered. Here, the parabola arrives late with respect to the sync pulse and V1 is driven into conduction for a longer interval. The net effect of this is to increase the average plate current of V1, make the control voltage more positive, and cause V2 to speed up—or to return to 15,750 Hz. Like a system of checks and balances, a wavering horizontal oscillator is gently prodded from side to side by the control voltage each time it attempts to wander.

The control voltage is an *average* value obtained by the integrating action of capacitor C3. The final potential used for control is built up over a few cycles of oscillator operation since C3 does not charge instantaneously to the peak voltage. A few synchronization pulses must be received before C3 reaches its stable state for perfect synchronization. This is an advantage because it makes the system immune to short, sharp noise pulses. Such interference could trigger the horizontal oscillator if the AFC system were one in which synchronization took place cycle by cycle. The averaging action of the cathode bypass capacitor and resistor is such that the dc control voltage fed to the grid of V2 changes gradually; hence, it does not respond to single, isolated pulses resulting from noise voltages.

AFC Controls

In most receivers two controls are provided for this AFC system: The *horizontal hold* is a potentiometer in series with the B+ supply lead which establishes the correct basic oscillator frequency of 15,750 Hz. It is then the job of the AFC system to prevent this from drifting, even slightly. The second control is generally labeled "horizontal locking range" and consists of a smaller trimmer capacitor in the grid circuit of the control tube (V1). This capacitor helps to phase the pair of incoming waveforms so that the sync pulse falls on the correct part of the parabolic waveform when the oscillator frequency is exactly 15,750 Hz.

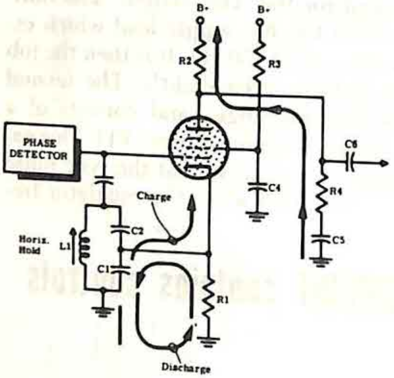
THE SYNCHROGUIDE AFC CIRCUIT contains controls

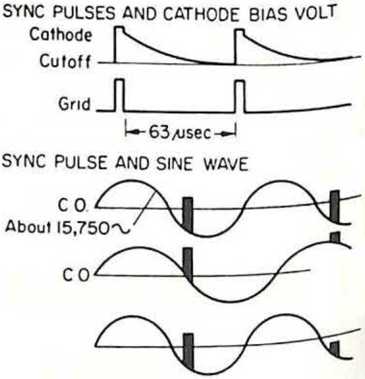


Horizontal AFC System with Another Type Oscillator

Here is another type of horizontal oscillator. This one, however, uses a tuned circuit consisting of L1, C1, and C2 to help establish the oscillator frequency with the help of cathode RC network R1 and C1.

In this type of horizontal oscillator, the tank circuit resonates at approximately 15,750 Hz, using a variable inductor to adjust the frequency. As the tank circuit resonates, it divides the ac voltage across C1 and C2. The ac voltage developed across C1 is also developed across R1 and is fed directly to the cathode. The alternating voltage is sufficiently high to drive the tube into saturation. When the tube conducts heavily, capacitor C1 charges from ground through the tube to the positive supply. This initial charging surge drives the tube far into cutoff. When the tube cuts off, capacitor C1 begins discharging from ground through resistor R1. Since the time constant of R1-C1 is about 63 µsec, the tube remains cut off until the tank circuit swings in the negative direction. The negative alternation drives the tube momentarily into saturation. Capacitor C1 recharges quickly through the tube, returning the circuit to cutoff. Thus, the tank circuit along with the charging and discharging of R1-C1 recycle the tube into short periods of conduction and long periods of cutoff. The *free running* frequency of the oscillator is slightly lower than 15,750 Hz, producing an output that recycles slightly longer than 63 µsec. The positive sync pulses that arrive at the grid occur slightly before the "free-running" time of conduction. Each sync pulse, therefore, sharply triggers the oscillator into conduction every 63 µsec.



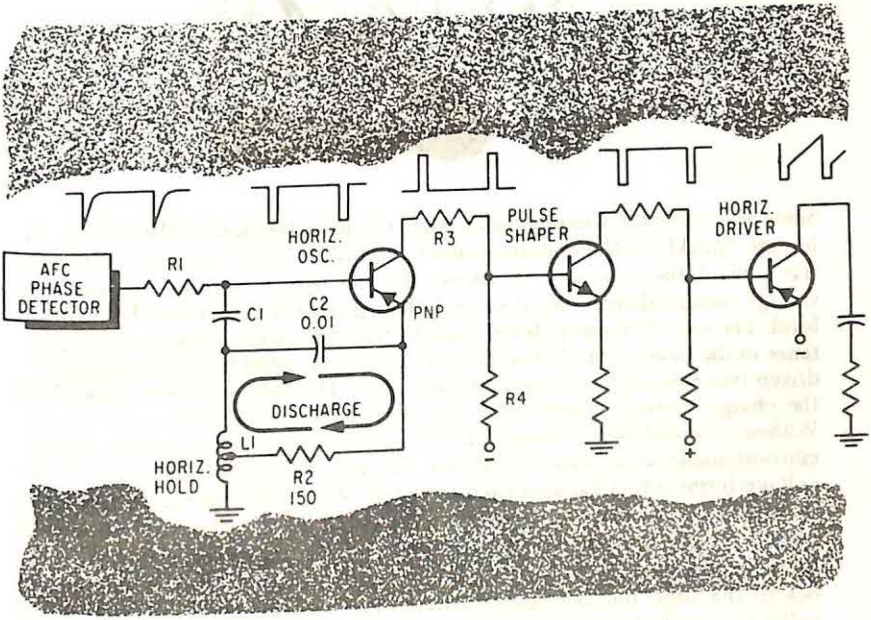


Now lets analyze what happens at the plate circuit. During the long periods when the tube is cut off, capacitor C5 charges through resistors R4 and R2 toward the positive supply. You'll remember that this circuit configuration develops a trapezoidal waveform at the plate. Thus, the sawtooth rises toward B+ value until the sync pulse momentarily triggers the oscillator into conduction. Now capacitor C5 discharges through R1 and the tube. The resulting waveform is coupled to the next stage through C6.

Transistor-Type Horizontal Oscillators

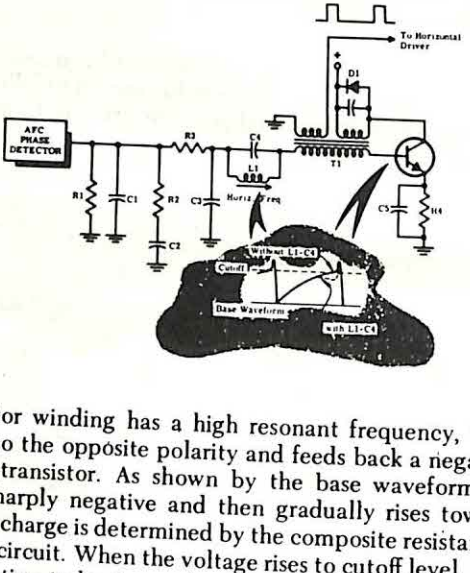
Next are a few common types of horizontal oscillators using basic variations of either the Hartley oscillator or blocking oscillator. In the Hartley-type horizontal oscillator the inductor L1 is center tapped and connected to the emitter through resistor R2 (at center tap) and capacitor C2 at the top end of the inductor. The circuit functions similar to the tube-type Colpitts oscillator we have just discussed. The ac voltage developed across the inductor is coupled through capacitor C2 to the emitter. When the PNP emitter becomes positive, and forward biases the transistor, the transistor drives swiftly into saturation. At this time, C2 charges from negative through R4, R3 and transistor to C2, L2 and ground. After a short period, the transistor is cut off as C2 discharges through R2 and coil, as shown by the solid arrow. This discharge path develops a negative voltage across R2, but gradually reduces in value until it reaches the forward bias or conduction state. The sync pulses, of course, trigger the base before the circuit reaches its free-running rate. The negative sync pulses drive the oscillator into saturation, causing C2 to charge once more, in preparation for the next cycle.

The collector output consists of an asymmetrical square wave having narrow positive and wide negative pulses. These pulses are fed to following stages such as the transistorized pulse shapers and pulse drivers to be formed into precisely the desired sweep voltage.



Transistor-Type Horizontal Oscillators (cont'd)

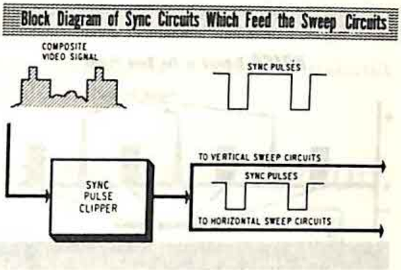
The transistorized blocking oscillator-type function is similar to the tube-type blocking oscillator that we covered earlier. There are two essential differences that you'll notice, however. This transistorized version incorporates a horizontal frequency control and transformer coupling to the horizontal driver stage. In this stage, the blocking oscillator uses an NPN transistor and, therefore, has the collector returned to a positive source, and the emitter returned to ground. Thus the transistor conducts from ground through R4, transistor, and transformer winding to the positive source. The voltage developed across the winding is transformer coupled to the base winding so that the base end of the winding is positive. Since this circuit uses an NPN transistor, the positive voltage fed to the base causes the transistor to conduct, resulting in a regenerative feedback. When the transistor conducts, a positive voltage is developed across C5 and R4 establishing self-bias for the circuit.

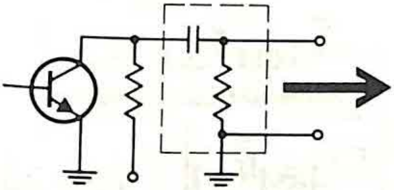


Since the collector winding has a high resonant frequency, the voltage alternates quickly to the opposite polarity and feeds back a negative voltage to the base of the transistor. As shown by the base waveform, the negative voltage swings sharply negative and then gradually rises toward the cutoff level. The rate of charge is determined by the composite resistance and capacitance in the base circuit. When the voltage rises to cutoff level, the transistor is driven into saturation to begin another cycle. The base waveform shows how the charge voltage appears with and without the stabilizing circuit L1-C4. Without the stabilizing circuit, the RC network in the base circuit charges conventionally at an exponential rate. As the voltage level nears cutoff, the voltage forms into a flat approach to cutoff. With a flat approach, any slight variations in the charging, changes in the cutoff level, or the introduction of noise can trigger the circuit too early. But with the stabilizing circuit (L1-C4), the tank circuit will resonate at 15,750 Hz and produce a ‘ dip’’ in voltage just before the time the sync pulse arrives. The voltage developed across the collector winding is transformer coupled to the horizontal driver stage.

1. *The Horizontal Sync Circuit Action.* The sync separator-amplifier furnishes two outputs: One which contains the vertical sync signal is fed to the vertical integrator, the other which may be considered to be the horizontal sync signal, is fed to the horizontal sweep oscillator.

Block Diagram of Sync Circuits Which Feed the Sweep Circuits

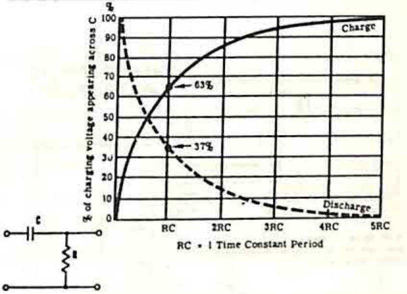




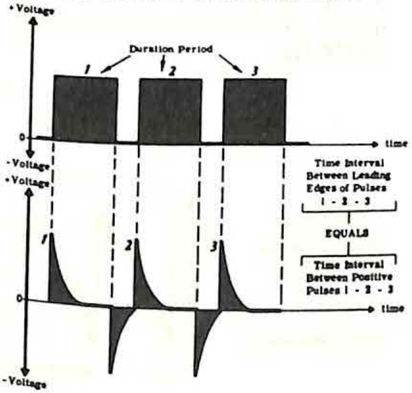
2. *The Differentiator* is located in the output system of the sync circuits. It consists of a simple combination of resistance and capacitance having values such that a square or rectangular pulse fed into the system will result in a sharply peaked output pulse.

3. *The RC Time Constant* of an RC circuit is defined as the product of the capacitance in farads and the resistance in ohms. By definition the time constant is the time required for the voltage to build up to approximately 63% of the applied voltage.

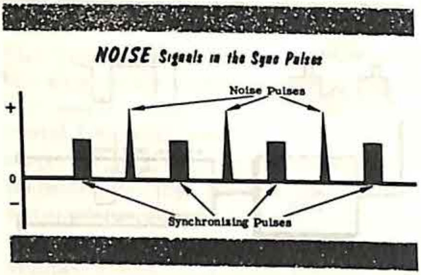
Charge and Discharge Curves



HOW THE DIFFERENTIATOR REACTS TO THE VERTICAL SERRATED PULSE.

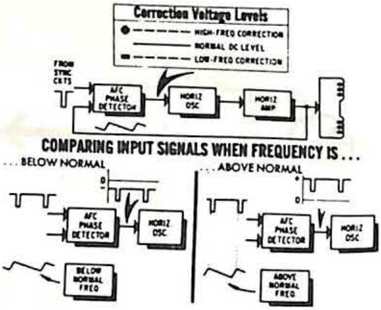

+Voltage
Duration Period
1
2
3
0
time
-Voltage
+Voltage
Time Interval Between Leading Edges of Pulses 1 - 2 - 3
EQUALS
Time Interval Between Positive Pulses 1 - 2 - 3
1
2
3
0
time
-Voltage

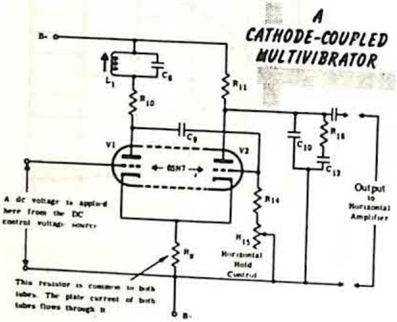
4. *The Effect of the Input Pulse Shape on the Differentiated Output.* If the input voltage pulse is of relatively long duration with short zero voltage intervals between, the negative pulse of the differentiated output for the trailing edge of the input voltage is very close to the positive differentiated pulse due to the leading edge of the adjacent input voltage pulse.



5. *Horizontal AFC.* Random noise pulses are present in the sync signal. These noise pulses often cause untimely triggering of the oscillator. Undesired signals of this variety can make the picture-tube electron beam move out of step with the electron beam in the television camera.

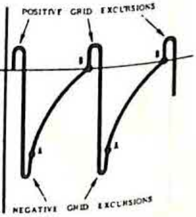
6. *The Horizontal AFC System* is designed to keep the horizontal oscillator "on frequency." It does this by using an AFC phase detector circuit to compare the frequency of the horizontal sawtooth with that of the incoming horizontal sync pulses.




A CATHODE-COUPLED MULTIVIBRATOR
B+
L1
C8
R10
R11
C9
V1
V2
6SN7
C10
R16
C12
R14
R15
Horizontal Hold Control
R9
B-
Output to Horizontal Amplifier
A dc voltage is applied here from the DC control voltage source
This resistor is common to both tubes. The plate current of both tubes flows through it

7. *Another Horizontal AFC System—Phase Detector.* The horizontal oscillator is a cathode-coupled multivibrator with an additional coil L1 in the plate circuit of one of the triodes to allow a certain amount of phasing adjustment. With the horizontal hold control potentiometer in its proper position, the output frequency of the multivibrator is about 15,750 Hz.

8. *Phase Detector.* In normal oscillation, the grid of the multivibrator tube is driven far down into the region below cutoff. The time interval which must elapse before the next positive pulse is obtained from the multivibrator is governed by the length of time needed for the grid voltage to decay back to cutoff over the path A to B in the diagram.

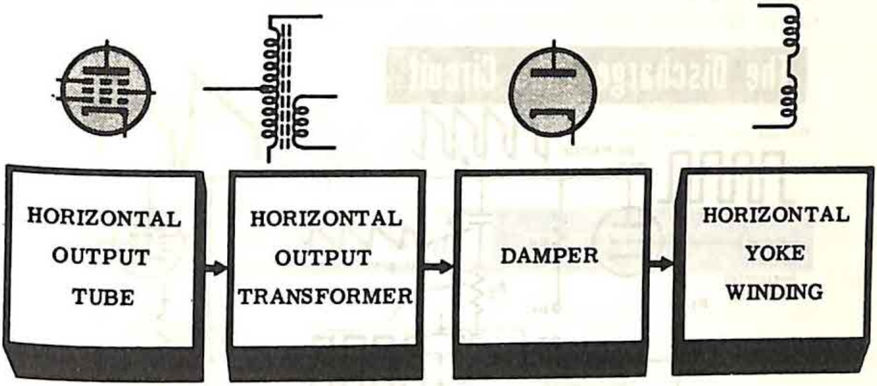


Grid Voltage Waveform of the Free-running Multivibrator without Interference

The Horizontal Sweep Circuit

The horizontal sweep circuit in many ways resembles the vertical sweep circuit previously discussed, as we can see in this block diagram.

Block Diagram of *HORIZONTAL SWEEP CIRCUIT*

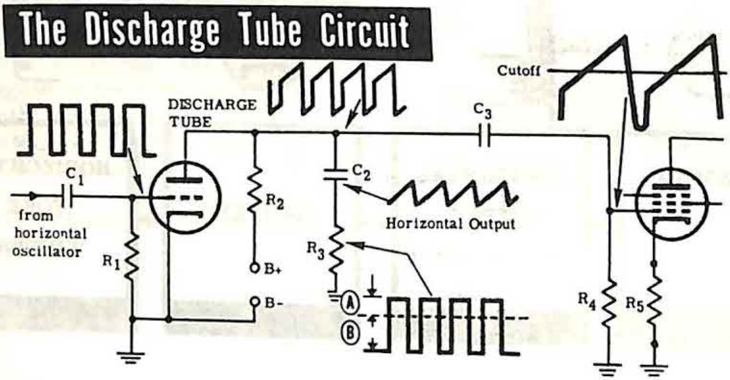


The final function of this system is to provide the necessary current waveforms to the horizontal winding in the picture-tube yoke for the purpose of sweeping the electron beam across the screen. The horizontal sweep action produces the scanning lines of which the image is composed. In addition, the horizontal output system supplies the high-voltage power supply with driving voltage, boosts the B+ from the low-voltage power supply to increase the efficiency of the horizontal output tube itself, and provides the pulses needed for the AFC system, automatic gain control arrangements, and the video blanking pulses.

As we shall see, the horizontal sweep section of the television receiver is unusual in that so many parts depend on other functions for their own proper operation. The horizontal output stage must receive a sweep voltage of the proper frequency and amplitude and shape, from the horizontal oscillator or discharge circuit. This sweep voltage is then fed to the horizontal output tube which provides horizontal sweep power to the deflection coils. To match the impedance of the deflection coils to the horizontal output tube we make use of the horizontal output transformer. The illustration shows also a damper section. This consists of a diode tube and associated circuitry that aids in the wave formation of the horizontal deflection currents in the deflection coils. During the operation of all this circuitry, a high-voltage pulse is developed across the horizontal output transformer that is used in obtaining high voltage for the picture tube. All this circuitry works together in a smoothly integrated network.

The Horizontal Discharge Circuit

In discussing the vertical output system, we noted that an arrangement called the *discharge circuit* is used in connection with the vertical oscillator to produce a voltage having the required waveform, i.e., the waveform needed to cause a sawtooth *current* to flow through the vertical deflection coils in the yoke. The same goes for the horizontal output system.


The Discharge Tube Circuit

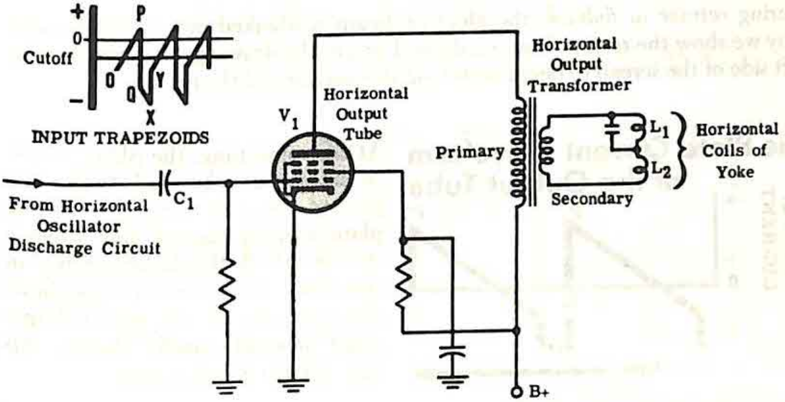
There are two general methods in use to produce the correct discharge waveform. The simplest of these uses a resistor and capacitor in the same arrangement as the discharge circuit discussed in connection with the vertical oscillator. In the diagram describing the AFC circuit using the cathode-coupled multivibrator on previous pages, R16 and C12 make up a network which produces the sawtooth waveform. In some receivers, however, a separate tube is used in combination with an RC network to form the output pulses into the desired shape. The resistance of R3 is low compared to that of R2. Capacitor C2 charges relatively slowly through the path formed by the sequence of B+ to R2 to C2 to R3 to ground or B−. Since the charging current is low and the resistance of R3 is relatively small, very little voltage drop appears across this resistor during the time that C2 is charging; this small voltage is shown at *A* in the waveform. When a heavy positive pulse from the horizontal oscillator appears at the grid of the discharge tube, the tube conducts suddenly and quickly discharges C2 and R3. This time a large negative voltage develops across R3, as shown at *B* of the resistor waveform. Thus, the charge-discharge cycle of capacitor C2 produces a *peaked* or square-wave voltage across R3 while, at the same time, giving rise to a sawtooth voltage across C2. The sum of these two voltages is, as we have seen in the case of the vertical output stage, a *trapezoidal* waveform. This is the voltage waveform needed to drive a *sawtooth* current through an inductive winding such as the horizontal deflection coil of the yoke.

The Horizontal Output Stage

The horizontal output stage in today's television receiver invariably consists of a high-efficiency type of power or beam pentode, an output (flyback) transformer, and associated small components. The other parts of the horizontal output *system*, in distinction to the output stage, may be listed as: the horizontal deflection coil in the yoke, the damper circuit, the high-voltage power supply, the B+ boost circuit, the linearity control and the width control. Let us analyze each of these in turn, starting with the horizontal output stage.

As we have seen, the grid input to this stage consists of trapezoidal voltage pulses from the discharge circuit which follows the horizontal oscillator. Consider a simplified output circuit like this:

The Horizontal Output Stage

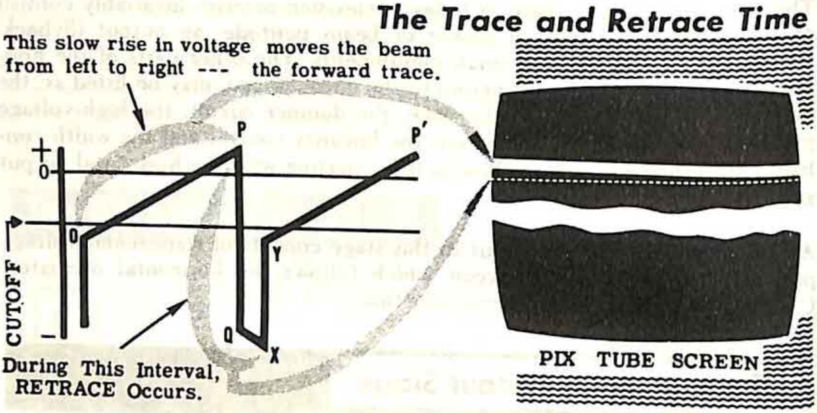


Trace and Retrace Time

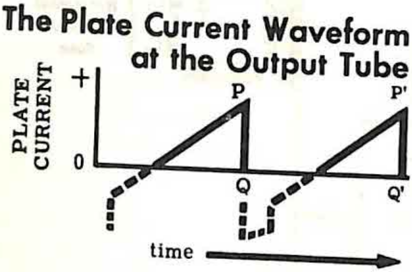
The voltage applied to the grid of the output tube rises at a steady rate from O to P. When it reaches P it takes a sharp drop in the negative direction to Q. Then there is a short interval while the voltage goes from Q to X, after which it rises suddenly to Y and starts a new cycle. The period from O to P represents *trace time* and the time from Q to X *retrace time.*

As the drawing shows, the *trace time* is the period during which the electron beam of the picture tube is being deflected uniformly, at a *relatively* slow rate across the face of the tube, leaving behind a flowing line which ultimately forms a part of the picture.

Trace and Retrace Time (cont'd)


The Trace and Retrace Time
This slow rise in voltage moves the beam from left to right --- the forward trace.
P
P'
+
0
O
Y
CUTOFF
–
Q
X
During This Interval, RETRACE Occurs.
PIX TUBE SCREEN

During *retrace* or *flyback*, the electron beam is blanked out. (That explains why we show the retrace line as a dashed line in the drawing.) It returns to the left side of the screen to begin sketching the next line of the picture.



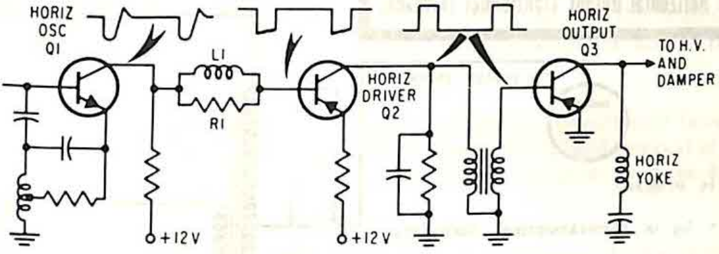
At the same time, the plate current of the output tube tends to follow a pattern like this illustration. Since plate current cannot flow when a tube is cut off, the dashed section of the plate current waveform shows that portion of the grid voltage-input beyond cutoff. During this time, plate current is zero.

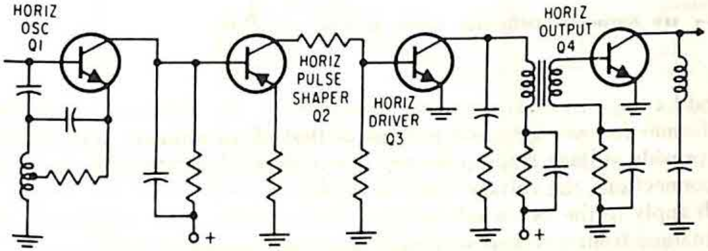
Essentially, the waveform is the same as that of the voltage applied to the grid of the output tube. It is all in the positive region, of course, since plate current cannot flow backward in a vacuum tube. Note the very sharp decline of current in each cycle from P to Q. *It is this very sudden drop in plate current which makes possible the generation of the high voltage needed for operating the picture tube.*

You will recall from your work in basic ac that the magnitude of an electromagnetically induced emf depends upon the *rate of change of current flowing in a coil*, among other things. If the current strength changes *rapidly*, the induced emf is *large*. Certainly, a greater rate of change of current than that which occurs from P to Q could hardly be realized anywhere. Hence, use may be made of this waveform in producing the extremely high voltages needed for the second anode of the picture tube.

Some Transistorized Horizontal Output Stages

Transistorized horizontal sweep circuits usually have one or more transistor circuits between the oscillator and the output amplifier. These intermediate stages help to shape and amplify the horizontal pulses before they drive the horizontal output amplifier. Generally, transistorized horizontal stages use transformer coupling to insure adequate impedance matching at the input and output of each stage. In addition, NPN and PNP transistors are commonly used in various combinations.

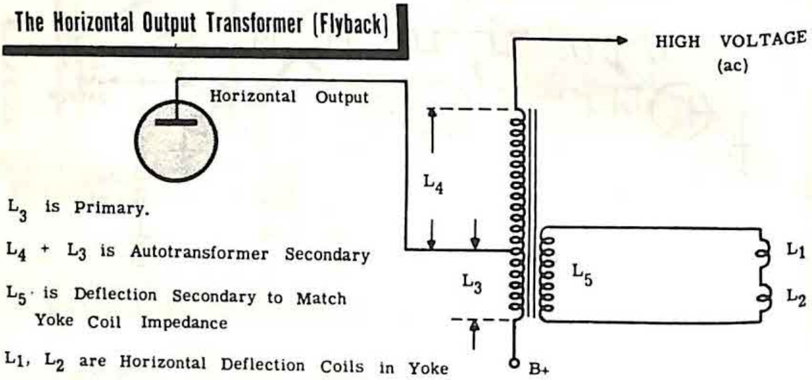




In the first horizontal sweep system, the horizontal oscillator is similar to the one you studied in the last lessons. The Q1 collector output feeds Q2 a series of short duration negative pulses through the peaking network consisting of L1 and R1. Since Q1 is directly coupled to Q2, the Q1 collector voltage establishes bias voltage for Q2. Thus, when the collector voltage swings in a negative direction, Q2 becomes forward biased and conducts heavily until Q1 collector voltage swings once more in a positive direction. Essentially, Q2 functions like a switch, closing and opening to the negative and positive alternations of the asymmetrical square wave from Q1. The horizontal output amplifier Q3 (PNP) functions like a switch also, conducting during the negative pulses and cutting off during the positive pulses develops the required sawtooth sweep current. In the second horizontal sweep system, the essential difference is the addition of the horizontal pulse shaper. The pulse shaper, however, is a dc coupled amplifier, having a dc coupled input and providing dc coupling to the horizontal driver Q3.

The High-Voltage Flyback Transformer

As the schematic diagram of the simple horizontal output stage shows, there is a coil in the plate circuit of the tube. As we shall show later, this coil is the primary of a transformer which is needed to provide the correct impedance match for the yoke winding L1 and L2. In practice, the transformer primary winding is modified by adding turns and extending the winding on the same core, in this fashion:

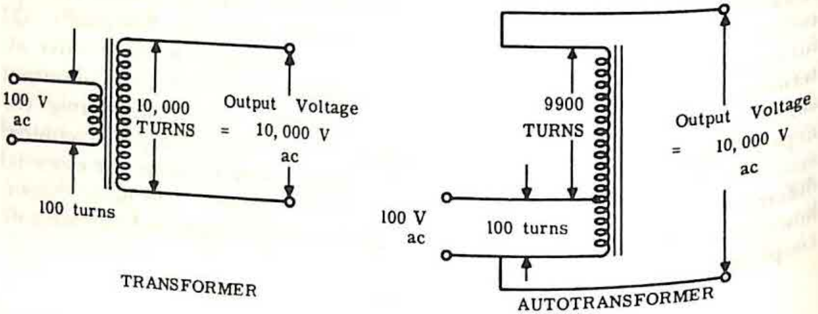


The Horizontal Output Transformer (Flyback)

Horizontal Output
HIGH VOLTAGE (ac)
L_4
L_3
L_5
L_1
L_2
B+
L_3 is Primary.
L_4 + L_3 is Autotransformer Secondary
L_5 is Deflection Secondary to Match Yoke Coil Impedance
L_1, L_2 are Horizontal Deflection Coils in Yoke

L3 and L4 together make up an *autotransformer*. The operation of this type of transformer follows the same pattern as that of an ordinary transformer. It may provide voltage step-up or step-down, depending upon its construction and connections, the voltage ratios being determined by the same simple rules which apply to the two-winding types. For example, the voltages that might be obtained from a typical autotransformer are compared with a similar two-winding transformer in this diagram.

The TRANSFORMER and the AUTOTRANSFORMER

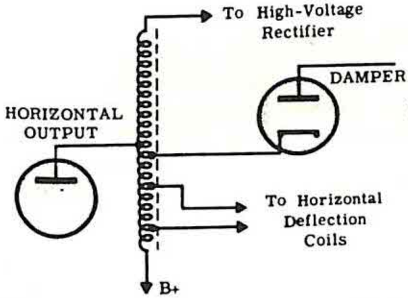


Two Types of Flyback Transformer

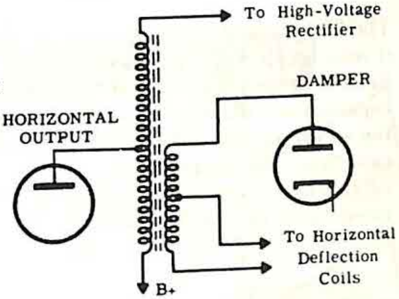
Returning to our output system, when the time for the flyback of the scanning beam arrives, the sharp drop in current flowing through L3 induces a high voltage across this portion of the winding. This in turn induces an *extremely* high voltage across the whole winding L4, since L4 contains many more turns than L3. If this high voltage is now rectified, we will have the dc voltage that the picture tube requires.

The horizontal deflection voltage appears across the secondary winding L5 by regular transformer action. Since L5 is matched to the impedance of the horizontal deflection coils L1 and L2, a large current having the waveform essential to proper sweep of the picture tube electron beam will flow in these coils. Later, we shall discuss this at greater length.

The horizontal output transformer is called the *flyback transformer* because the high voltage just discussed is developed during the *flyback* interval of the scanning voltage. Two types of horizontal output transformer have been widely used.



TRANSFORMER-TYPE FLYBACK



ISOLATION-TYPE FLYBACK

The two-winding or "isolation" type flyback transformer was used mostly in the early days of television. The autotransformer flyback has since gained in popularity and is used widely in modern television receivers. In the autotransformer type flyback there is just one continuous winding, with taps for the high-voltage rectifier, horizontal output tube, damper, horizontal deflection coils, and B+. The only important difference between the two types is that the voltages fed to the damper and horizontal deflection coils will be inverted in one with respect to the other. This is the result of the separate secondary in one and not in the other.

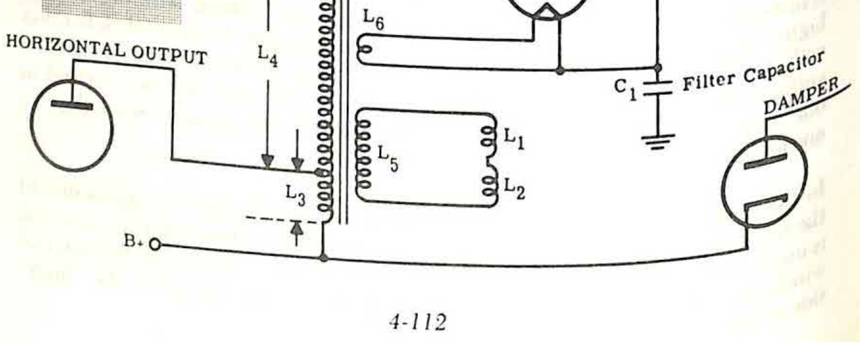
In the diagrams of the output circuit, there is a small capacitor across one of the horizontal deflection coil windings. This is called a balancing capacitor and is used to prevent coupling between the vertical and horizontal deflection coil windings in the yoke. For proper balancing it is connected across the "high" side of the horizontal deflection coil.

The High-Voltage Power Supply

The output voltage at the top of the flyback transformer has a very high ac potential with reference to ground. The second anode of the picture tube requires dc, however, so the flyback output must be rectified and filtered. To the previous circuit we have added a high-voltage rectifier tube, a filter resistor R1, and a filter capacitor C1. One of the most interesting features of the circuit is the method whereby the high-voltage rectifier obtains its filament power. One or two loose turns, well sheathed in high-voltage insulating tubing, are usually placed near L5 around the same core. Since most high-voltage rectifiers require about 1.5 V across their filaments, enough voltage is induced in these turns to do the job.

The high-voltage rectifier is connected in a simple half-wave rectifier circuit. Each time the plate is made positive by the voltage pulse in the flyback transformer, current flows from filament to plate, through L4 and L3, through the low-voltage power supply to ground and back to the filter capacitor C1. Thus, C1 charges to the peak voltage of the high-voltage ac—often as much as 20,000 V in modern 21-in. receivers. This voltage is then applied directly to the second anode of the picture tube.

The filter capacitor must have a very high voltage rating, of course; otherwise it may break down and destroy itself. Fortunately, its capacitance does not have to be very high so that the capacitor can be quite small. Even with small capacitances, filter capacitors can provide adequate filtering action, as long as the ac voltage applied to the rectifier is high in frequency. Certainly, this is the case here. The frequency is 15,750 Hz—the frequency of the horizontal oscillator that supplies the pulses required by the flyback transformer. The usual capacitance of C1 is 500 $\mu\mu$F.

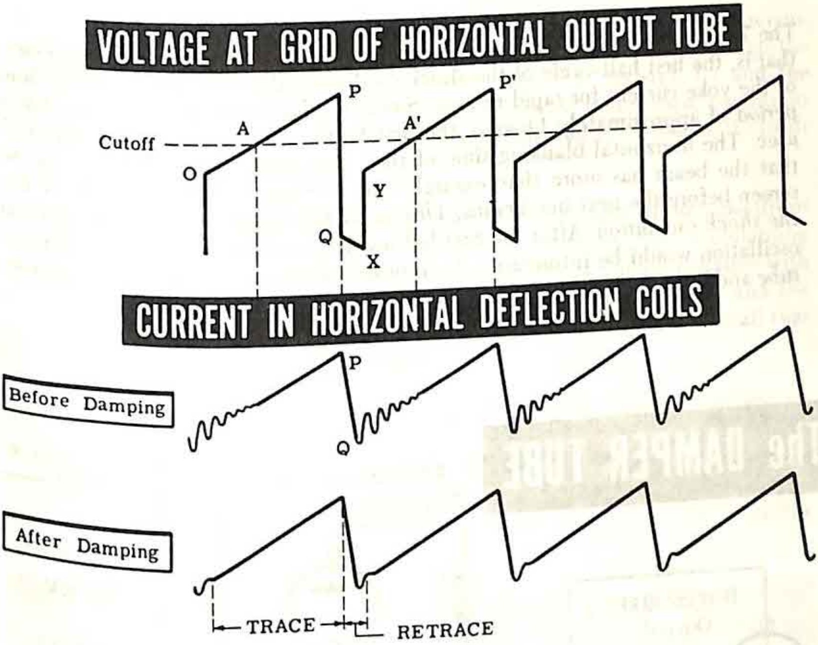


High-Voltage Power Supply

The Damping Circuit

In the vertical output system, a pair of damping resistors connected across the vertical deflection coils was sufficient to prevent the effects of ringing or shock oscillation in the coils. However, due to the high scanning frequencies involved in the horizontal deflection system, damping resistors cannot do the job adequately.

These waveforms show the effect of the changing output tube grid voltage upon the deflection coil current and voltage.


VOLTAGE AT GRID OF HORIZONTAL OUTPUT TUBE
P
P'
A
A'
Cutoff
O
Y
Q
X
CURRENT IN HORIZONTAL DEFLECTION COILS
Before Damping
P
Q
After Damping
TRACE
RETRACE

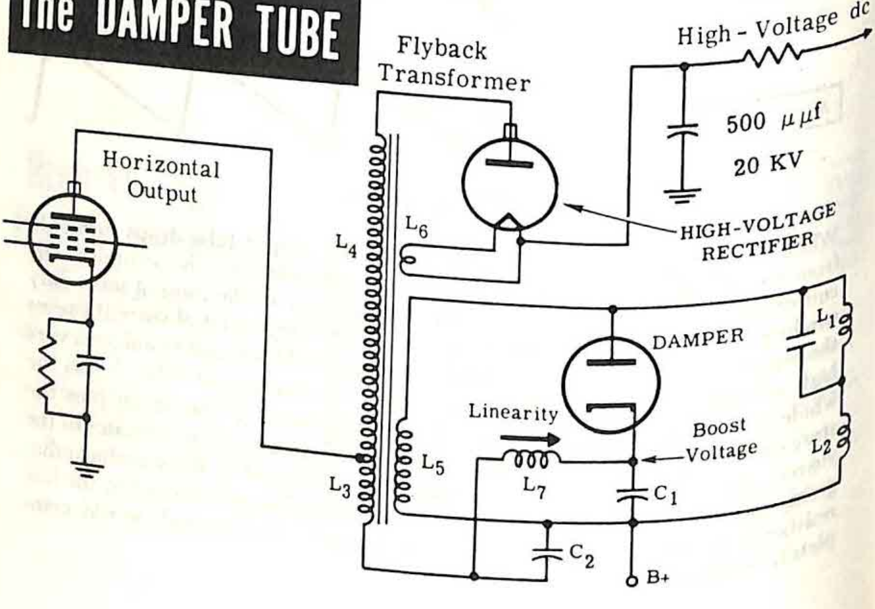
When the voltage at the grid of the horizontal output tube drops suddenly from P to Q, the plate current of the tube cuts off suddenly. The secondary circuit of the stage contains a great deal of inductance in the form of secondary winding L5 and deflection coils L1 and L2. The sharp cutoff of current causes the magnetic field around L1 and L2 to collapse suddenly and to induce a very high voltage across L1 and L2 in the form of a counter emf. This shocks the whole system into self-oscillation. All the inductance in the circuit plus the stray capacitances that are present form a tuned circuit which resonates in the vicinity of 70 to 80 kHz. These oscillations, as pictured in the waveform diagram, continue for a large part of the cycle before being dissipated in the low resistance of the coils and, if permitted to occur unhampered, would completely destroy the picture quality.

The Damping Circuit (cont'd)

However, there is a need for a definite portion of this shock oscillation: should no oscillation occur, the energy stored in the yoke as a result of the sharp current change in the tube would be dissipated very slowly. This would result in a slow decay of the sawtooth current in the deflection winding. A lingering decline of this nature is very detrimental because the flyback (retrace) is not completed before the next scanning line appears. This produces an effect called horizontal foldover, where the picture folds back over on itself.

The 70–80-kHz oscillation permits a heavy inductance to exhibit a *fast* decay; that is, the first half-cycle of the shock oscillation (P to Q) speeds the decline of the yoke current for rapid retrace. Since oscillation of this frequency has a *period* of approximately 14 μsec, the first half-cycle is completed in about 7 μsec. The horizontal blanking time of the video signal is close to 10 μsec, so that the beam has more than enough time to return to the left side of the screen before the next line begins. *This could not happen without the help of the shock oscillation.* After the first half-cycle is completed, however, further oscillation would be intolerable. Its removal is accomplished by the *damper tube* and its associated circuit.

The DAMPER TUBE



The Damping Circuit (cont'd)

As you examine the circuits, you note the following:

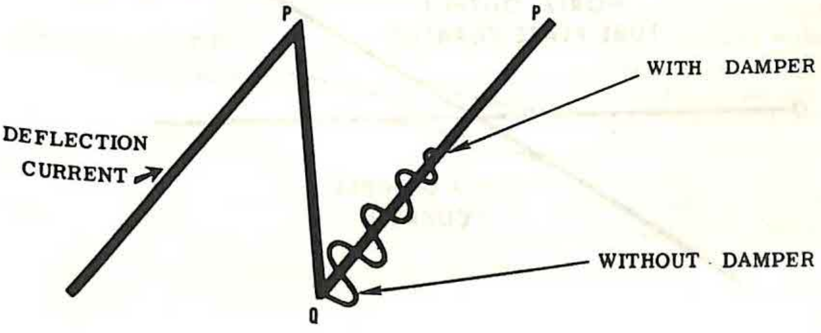
1. The damper tube is a diode which is connected in parallel with the horizontal deflection coils L1 and L2. The capacitance of C1 is chosen so that its reactance at 15,750 Hz is negligible.
2. The B+ voltage supply to the plate of the horizontal output tube now follows a path through the damper tube, through L7 (the linearity coil which will be discussed shortly) and finally through L3 to the plate.

During the interval A-P of the forward trace the horizontal output tube is conducting. Throughout this period, current flows up from ground through the cathode resistor, the output tube, down through L3, through L7 and the diode, to B+. No shock oscillation can possibly occur under these conditions because the horizontal output tube is acting as the damper—that is, it "loads down" the deflection coils.

At the completion of the line-scanning interval, the current in the yoke drops sharply (P to Q). The voltage across L1 and L2, produced by the collapsing magnetic field, reverses, making the plate of the damper diode negative with respect to its cathode. In this condition, it becomes an open circuit and the half-cycle of oscillation (P to Q) takes place unhampered. You will recall that this half-cycle is essential for fast retrace.

At the completion of the half-cycle (point Q), the yoke current reverses, attempting to continue the damped oscillation. As it does so, the plate of the diode becomes positive with respect to its cathode due to the reversed voltage drop, the diode conducts, and causes the yoke current to fall slowly and linearly toward zero. Contrast this low, even decay with the oscillatory decay shown below.

ACTION of the DAMPER TUBE



The Damping Circuit (cont'd)

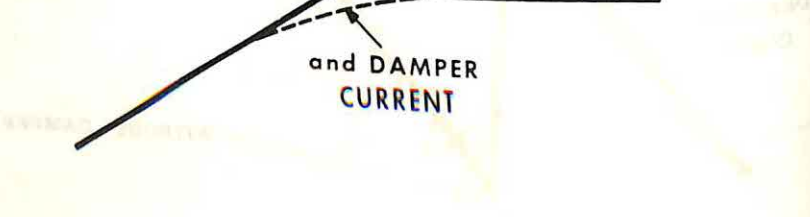
Once the yoke current decays to zero, the output tube conduction cycle again takes over, maintaining a uniform, linear rise of yoke current as required for proper sweep.

Until now it was assumed that yoke current flowed during the entire linear rise in horizontal output tube grid voltage. While this is true, it is not all the result of grid voltage. Recall that approximately one-third of the grid waveform occurred while the horizontal output tube was cut off. Thus, plate current flow in this tube accounts for only two-thirds of the yoke sweep current waveform.

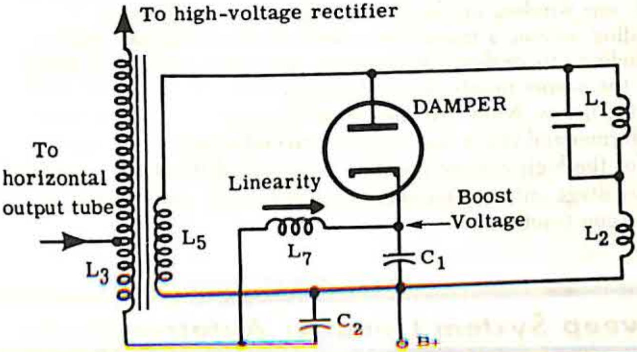
The diagram shows how plate current flows at point A and continues for about two-thirds of the yoke current waveform. When the grid voltage drops suddenly into cutoff, the magnetic field around the horizontal deflection coils collapses, shock-exciting the horizontal output system, as described, moving the beam from right to left (retrace). When the beam has completed its retrace and is at the left side of the screen, the damper begins to conduct (B), and places a heavy load across the deflection coils. This damps the oscillations and provides the sweep current for the first one-third of the deflection-coil current waveform.

As the rate of energy decay becomes nonlinear, the horizontal output tube, which has been in cutoff during retrace and the first one-third of the horizontal sweep, begins to conduct. With proper adjustment of the linearity coil, the damper decay and the start of horizontal-output tube conduction are arranged so as to increase and give the current waveform in the deflection coils an even rise.

SWEEP CURRENT IN YOKE IS MADE UP OF...



The Auxiliary Low Voltage Supply—Boost Voltage



The DAMPER TUBE

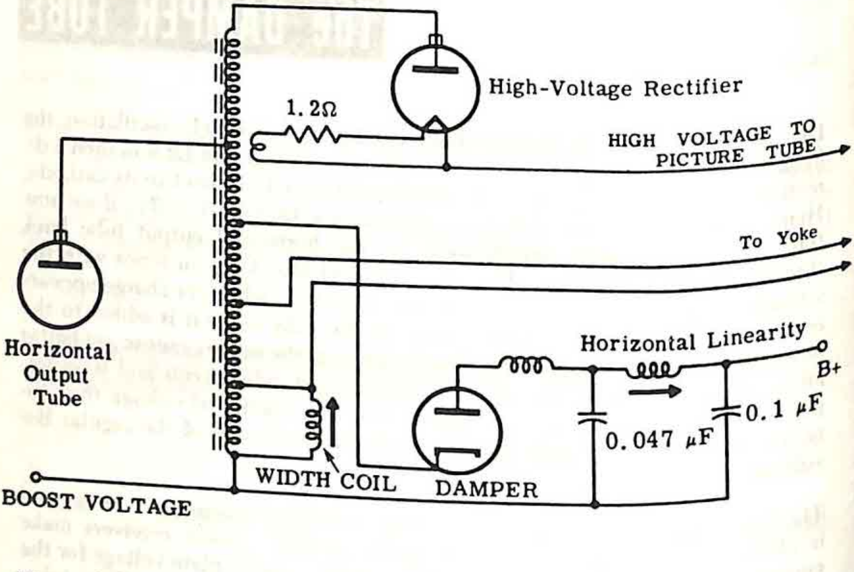
During the time that the damper diode conducts, to stop yoke oscillation, the flyback voltage developed across the deflection coils L1 and L2 is in such a direction as to make the plate of the diode positive with respect to its cathode. Hence, current flows and charges C1 *positively with respect to B+*. If we now trace the plate voltage supply path for the horizontal output tube back through L3, L7, and C1 to B+, it is apparent that C1 is in series with the voltage applied to the output tube plate. Therefore, whatever charge appears on C1 (due to the self-induced voltage in the yoke coils) it is added to the normal low-voltage supply. This "boost" permits the set designer to get better efficiency and output from the horizontal output tube circuit and is an important function of the damper tube circuit. The additional voltage thus obtained often ranges as high as 200 V or more above that of the regular B+ voltage.

The boost voltage developed is sometimes called the "bootstrap" voltage and is often indicated on schematic diagrams as B++. Many receivers make considerable use of this higher voltage, using it to supply plate voltage for the vertical output tube, picture tube elements, and the horizontal oscillator tube. In this respect, failure of the boost circuit can cause television troubles that may at first be deceiving. For example, boost voltage failure or trouble in a receiver may cause loss of vertical deflection, or loss of horizontal synchronization. It could even cause a loss of high voltage by reducing the output from the horizontal oscillator. When applied to the picture tube, low boost voltage could cause a loss of brightness or poor focusing.

Other Forms of Horizontal Output Circuits

Some manufacturers prefer the autotransformer type of output system in which there is only one winding on the horizontal output transformer. As explained in a preceding section, a transformer need not have separate primary and secondary windings to perform step-up or step-down action. A single winding tapped at the proper points can be designed to do the same job. Such a system is illustrated below. Note that the connections are very similar to the two-winding transformer and that a one- or two-turn coil is still used to pick up filament voltage for the high-voltage rectifier. A circuit of this type provides for damping, high-voltage output, and horizontal deflection, and is somewhat more economical in construction.

Horizontal *Sweep System* Using an *Autotransformer*

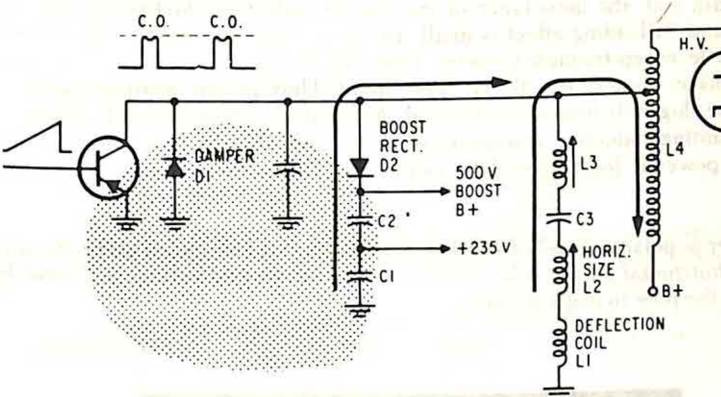


Most television receivers use autotransformers in the high-voltage deflection system. Fundamentally, the only real difference the autotransformer introduces, as compared to the conventional transformer, is in the polarity of the damper elements. In the diagram above, the cathode of the damper is connected at a point high up on the transformer winding. This is opposite to the connection found in conventional transformers. The phase reversal is due to the fact that the usual primary-secondary phase inversion is missing in the autotransformer.

Solid-State Horizontal Output Circuits

A popular solid-state horizontal output circuit uses a transistor as a horizontal output that shunts the deflection circuits as shown in the circuit below. The transistor operates sharply between cutoff and saturation, thus functioning as a switch to open and close the transistor circuit.

To begin our analysis of the circuit, let's trace the current path through each parallel leg to B+. The transistor finds its dc path to B+ through autotransformer L4, while the boost B+ network sees a charge path from ground through C1, C2, D2, and L4. The deflection network establishes its charge path from ground to B+ through L1, L2, C3, and L4. Since damper diode D1 is reverse biased because its cathode faces B+, the diode is essentially an open path from ground to B+.



As the transistor operates between cutoff and saturation, it periodically interrupts current through L4 and thus initiates flyback action in the high voltage circuit. A portion of the high voltage developed across L4 is tapped for use across the boost voltage circuit. When voltage across L4 swings positively, boost rectifier D2 conducts and allows capacitors C1 and C2 to charge and establish the required value of B+ voltage. Since the voltage across L4 can swing dangerously negative to forward bias the collector-to-base junction of the transistor, damper diode D1 is connected across the diode to dampen negative voltages.

As the transistor alternately swings from cutoff to saturation, the voltage across the deflection network causes current to alternately sweep through deflection coil L1. By varying the inductance of coil L2, we can change the amount of current through the network and thus change the size, or width, of horizontal sweep.

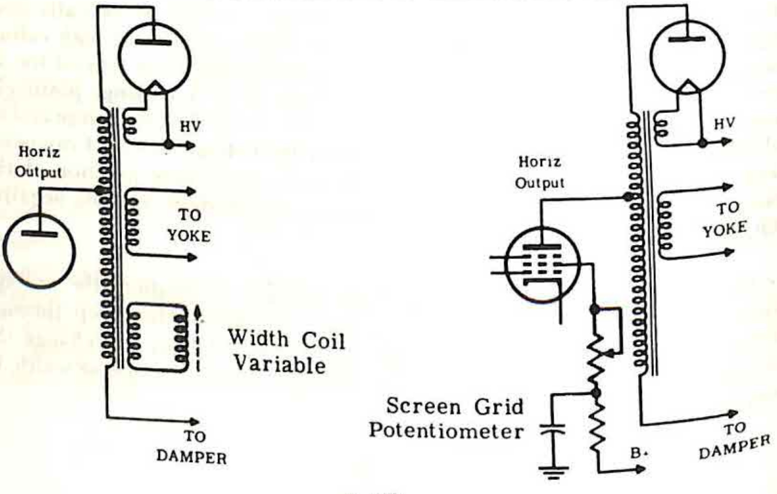
The Horizontal Size or Width Control

A television picture is transmitted with an *aspect ratio* (ratio of width to height) of 4:3. Unless this ratio is maintained in the receiver, all the objects in the televised scene will be uncomfortably distorted; figures will appear taller and thinner, or shorter and broader than they should be. As we saw in the discussion of the vertical output system, there is a vertical *height* control which permits the service technician to fill the screen area in this direction. After the height of the picture is correctly set, the *width* of the picture must be adjusted. This adjustment is made by the *width control* or *horizontal size control.*

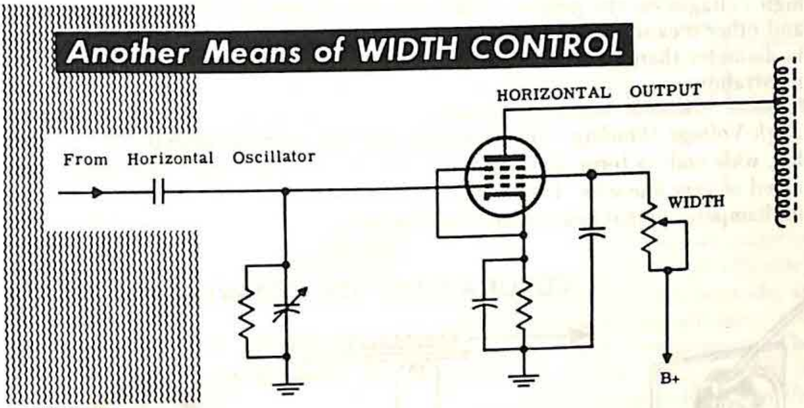
One type of control, a variable coil in series with the horizontal deflection coil, was described on the previous page. In many receivers, the width control takes the form of a slug-adjusted coil connected across a part of the horizontal output transformer secondary winding. With the slug inserted all the way into the width coil, the inductance of this unit is high, its inductive reactance is large, and its loading effect is small. In this position the width coil removes very little sweep-frequency energy from the horizontal output transformer, and behaves more or less like an open circuit. Thus, picture width is *maximum* with the slug fully inserted in the coil. As the iron core is gradually removed, the shunting inductive reactance decreases and absorbs power so that less sweep power is fed to the deflection coils. This action reduces the picture width.

Another popular method of width control is varying the screen grid resistance of the horizontal output tube. This varies the screen grid voltage and thus the gain of the tube to control width.

PICTURE WIDTH can be CONTROLLED by...



The Horizontal Size or Width Control (cont'd)


Another Means of WIDTH CONTROL

Constructional Features of Horizontal Output Transformers

Very high pulse voltages are present in output transformers. Therefore, the transformers must be designed to avoid high-voltage arcing and *corona*. Also, the transformer must be designed for a high Q to obtain high efficiency. These demands necessitate a completely different approach to the problem of construction. Let us examine the essential features of a typical transformer by tracing the fabrication, starting with the iron core.

The Iron Core. This is the frame that supports the windings and provides the required rigidity. It may be made of ferrite, flaked iron, or thin laminations of high grade transformer steel. The air gap, an important part of the core, has the function of preventing magnetic saturation of the iron due to the direct current that flows in the primary winding. It will be recalled that the horizontal output stage current flows through a portion of the primary and that this current is quite high. Unless the magnetic flux path is broken by a gap, saturation would occur quickly and the transformer losses would rise to intolerable figures.

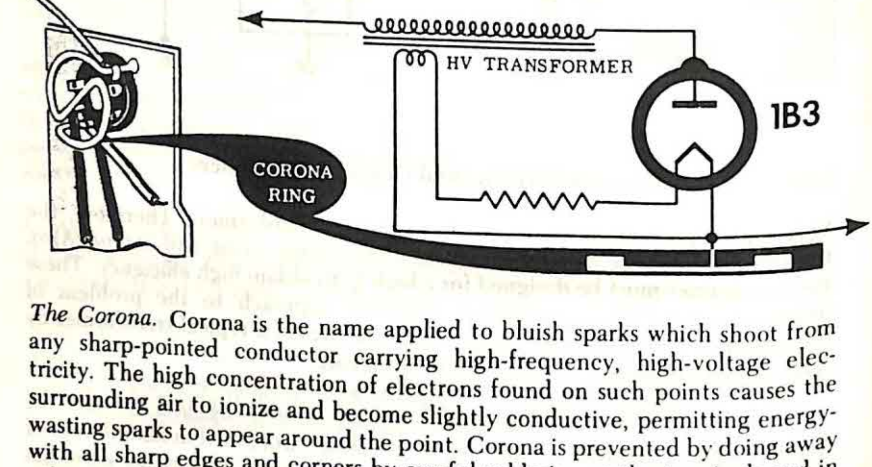
Sweep Output Secondary. A fiber strip, encircling the top of the core, is used as the base upon which the sweep output secondary winding which feeds the yoke is wound. This coil carries the heavy yoke currents, hence must be wound with relatively thick wire. To obtain the necessary inductance with wire of this size, the sweep secondary must be wound over a great enough length of the core. Thus, it is the longest winding of the transformer. Its ends and any taps it may have are brought out to terminal lugs on Bakelite panels fastened to the core.

Horizontal Output Transformers (cont'd)

Primary. This winding is of finer wire and is wound on several layers of insulating tape which cover the outside of the sweep secondary. The presence of high voltages on the primary leads necessitates the use of high-voltage *dope* and other measures intended to prevent arcing. The primary winding is larger in diameter than the sweep secondary but not as wide, as may be seen in the illustration.

High-Voltage Winding. This is wound directly over the primary; it is a very flat, wide coil—a form of construction which encourages high Q—being fabricated of very fine wire. The current it must carry is only on the order of a few milliamperes so that heavy wire would be unnecessarily costly and bulky.

CORONA RING FOR HIGH-VOLTAGE RECTIFIER

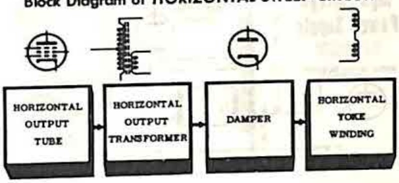


The Corona. Corona is the name applied to bluish sparks which shoot from any sharp-pointed conductor carrying high-frequency, high-voltage electricity. The high concentration of electrons found on such points causes the surrounding air to ionize and become slightly conductive, permitting energy-wasting sparks to appear around the point. Corona is prevented by doing away with all sharp edges and corners by careful soldering at the terminals and in other ways. The corona ring, a ring of thick metal about 1 in. in diameter sometimes found under the high-voltage rectifier, prevents corona by distributing the high potentials around a large, smooth surface. Wax impregnation is used on the entire transformer assembly to present a smooth surface to the air for corona prevention. A wax "tire" is secured to the outer edge of the high-voltage winding for the same purpose.

The Filament Wires. Potential for the filament of the high voltage rectifier is obtained from a few turns of well insulated wire loosely coupled to the transformer core. Often, a low-value fixed resistor is used in series with the filament turns and the filament of the rectifier. This maintains the filament voltage at its proper value for the particular transformer type and arrangement of filament wire loops.

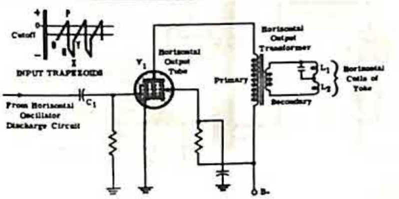
1. *The Horizontal Sweep Circuit.* The sweep voltage is fed to the horizontal output tube which provides horizontal sweep power to the deflection coils. To match the impedance of the deflection coils to the horizontal output tube we make use of the horizontal output transformer. A damper tube is inserted between the transformer and the deflection coils.

Block Diagram of HORIZONTAL SWEEP CIRCUIT

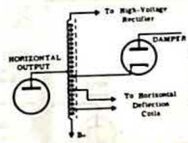


2. *The Horizontal Output Stage* invariably consists of a high-efficiency type of power or beam pentode, an output (flyback) transformer, and associated small components. The grid input to this stage consists of trapezoidal voltage pulses from the discharge circuit which follow the horizontal oscillator.

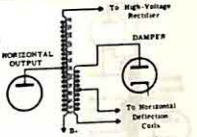
The Horizontal Output Stage



3. *Two Types of Flyback Transformer.* Two types of horizontal output transformers have been widely used. The two-winding or isolation type flyback transformer was used mostly in the early days of television. In the autotransformer type flyback, there is just one continuous winding, with taps for the high voltage rectifier, horizontal output tube, damper and horizontal deflection coils, and B+.

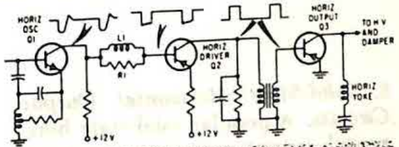


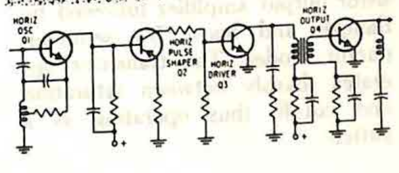
TRANSFORMER-TYPE FLYBACK

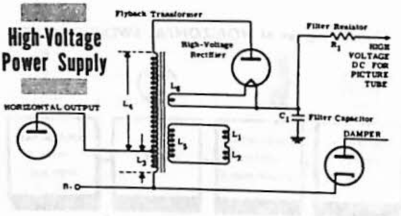


ISOLATION-TYPE FLYBACK

4. *Transistorized Horizontal Sweep Circuits.* The horizontal sweep circuits usually have one or more transistor stages between the oscillator and output amplifier. These intermediate stages help to shape and amplify the horizontal pulses before they drive the horizontal output amplifier.

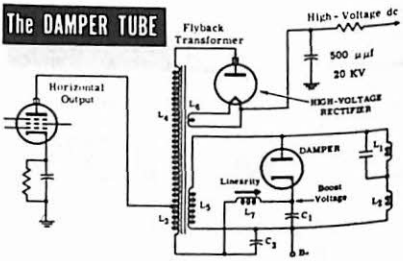


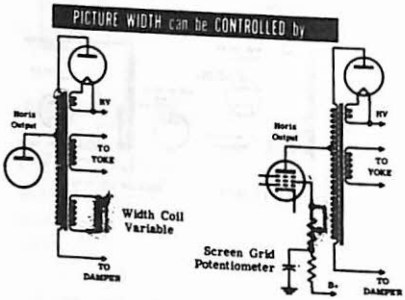




5. *The High-Voltage Power Supply.* The very high ac potential at the top of the flyback transformer must be rectified and filtered before it can be applied to the second anode of the picture tube. A high-voltage rectifier tube, filter resistor and filter capacitor are added to the previous circuit.

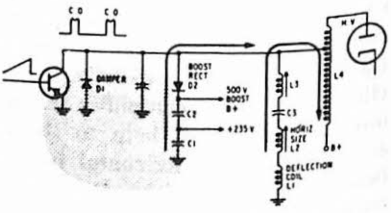
6. *The Damping Circuit.* As you examine the circuits, you note the following: the damper tube is a diode which is connected in parallel with the horizontal deflection coils L1 and L2. The capacitance of C1 is chosen so that its reactance at 15,750 Hz is negligible.





7. *The Horizontal Size or Width Control.* After the height of the picture is correctly set, the width of the picture is adjusted with the width control or horizontal size control. In many receivers the width control takes the form of a slug-adjusted coil connected across a part of the horizontal output transformer secondary winding.

8. *Solid-State Horizontal Output Circuits.* A popular solid-state horizontal output system uses a transistor output amplifier followed by damper and boost B+ semiconductor diodes. The transistor operates sharply between saturation and cutoff, thus operating as a switch.



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